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and

Atmospheric Electricity

(Now entitled Journal of Geophysical Research)

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Terrestrial Magnetism
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VOLUME 31 MARCH, 1926 No. 1

THE PRINCIPLES OF THE SYSTEMATIC APPLICATION OF GEOPHYSICAL METHODS OF PROSPECTING TO MINING AND SUBTERRANEAN ENGINEERING.[1]

BY RICHARD AMBRONN, *Göttingen.*

Until a few years ago the research work accomplished by the geologist and the mining engineer for investigating the formations of mineral deposits in the Earth's crust—whether the object be purely or practically scientific—was confined almost exclusively to ascertaining and systematically arranging such empirical facts as could be derived by direct observation at easily accessible places on the surface of the globe, e. g., at exploring works, borings, or existing mines. The miner has been accustomed to say: "Behind the shoulder it is dark," meaning thereby that the only facts to be taken into serious consideration as a certain basis for his technical and economic ventures and plans were those which he could observe with his own eyes. To such observations may be added all those which may be obtained by petrographic, chemical, or microscopic examinations of specimens taken from the localities in question.

The greater the progress of mining technique, the greater the depth at which ore, etc., can be profitably exploited. And on the other hand, the valuable deposits which can be discovered, and evaluated, by prospecting on the surface of the Earth only, are becoming more and more exhausted, so that one is obliged more and more to exploit formations lying in lower strata. The deeper these strata, the more difficult it becomes to draw, from the geological facts ascertainable on the surface, any reliable conclusions as to the conditions prevailing at these greater depths; at the same time the costs increase proportionately for the prospecting work requiring boring, sinking of shafts, and so forth. Thus the increased depth of the deposits involves a disproportionate increase of risk, when the old methods only are employed.

A further disadvantage of these direct investigations is that, as a rule, the observations can only be made at test points distributed over large areas, unless exceptionally favorable conditions have been provided by Nature, or exceptionally large sums are

[1] Abstracted, with the permission of the publisher Theodor Steinkopff, Dresden Blasewitz, from the "Principles of Applied Geophysics" by Richard Ambronn, to be published shortly.

available for the investigations. When observations are thus made at test points only, the nature of the rock or deposits between them can only be surmised by drawing conclusions from analogous situations, and the uncertainty of these surmises has frequently led to bitter disappointments. And at the present day, when the profitableness of a mining undertaking is so largely dependent on a strictly systematic and organized output of the greatest possible uniformity in quality and quantity, precise knowledge of the extent and nature of a deposit is of the utmost importance for working out suitable exploitation projects. An error in such cases is exceedingly difficult to correct.

For this reason many efforts have been made, during the last few decades, to develop methods of investigating geological structure and deep-lying strata, which dispense with the necessity of actually reaching the formations to be examined, the principle followed being that of investigating the properties of such valuable deposits, or of the stratification regularly accompanying them, in so far as these are capable of exercising adequate *action at a distance.*

A large number of economically-valuable deposits—though by no means all, in so far as we can ascertain at the present stage of our knowledge and research—actually possess physical properties thus acting at a distance. The tasks set the investigator by the geologist and the miner will thus have to be carried out with the systematic aid of all our present appliances of physics and geophysics, in order that we may ascertain the extent of the practical applicability to the purpose of investigating the formations and deposits of the Earth of those physical properties of matter which are in any way connected with action at a distance, and whose laws have already been established and are known in physics.

By means of apparatus specially constructed for this purpose, aided by suitably adapted processes, the existence and dimensional relations of long-distance action thus arising out of the depths must be measured at a sufficient number of accessible and suitably distributed points. The extent to which the results of these measurements of action at a distance permit the drawing of definite conclusions as to the nature of the formation of the lower stratification depends upon a careful investigation of the specific physical properties of the various materials forming the crust of the Earth, and upon the mathematical laws governing the propagation of their long-distance action, that is, upon the properties of the field of magnetic or other forces generated by these materials, or of lines of force influenced by them. The care and comprehensive expert knowledge brought to bear upon this research are indicative of the economic and practical value of the physiographical methods of investigating the surface of the globe.

The especially characteristic properties of some minerals have long induced mining prospectors to endeavor to make use of these physical peculiarities for the purpose of finding deposits suitable for exploitation. The magnetic iron ores must first be mentioned

in this category. Towards the middle of the 19th century methods had been worked out in Sweden for utilizing magnetic measurements to detect iron ores. The high degree of electric conductivity and the electrochemical action of many sulphurous ores (pyrites, sulphide of lead, etc.), as compared with the rock formations, were recognized in England and Germany at the beginning of the 19th century, and experiments were made for their utilization in prospecting for deposits of such ores.

These first attempts did not however lead to the systematic application of geophysical methods for prospecting purposes. The main reason for this has been that at that time the observations were not made by physicists well versed in the physical principles and conditions involved in such methods of surveying, but by mining engineers not possessing a sufficient grasp of the physical difficulties involved, and of the procedure to be followed for elimination of these difficulties. Thus on some occasions favorable results were obtained, while in other and more complicated cases, the results were disappointing. Until very recently, mining and geology on the one hand, and physics on the other, have had so little in common that no efficient cooperation has been possible. It has only been since scientific physics and geophysics have been sufficiently developed in themselves, that the last few decades have witnessed the beginning of a cooperation which has rapidly led to the present high degree of development and extensive use of geophysical methods in mining work. Geophysics, which at first served solely the purely scientific aim of studying the structure of the globe, has greatly contributed to this development. In the sphere of physics and physiographic geodesy there have been simultaneous developments in the calculation of gravities and densities, again serving at first a purely scientific aim, viz., that of determining the real formation of the Earth's surface and its relative stability.

In this manner the first impetus was given to systematic work on the physical and geophysical methods dealing with the exact study, with the aid of instruments, of every description of action at a distance emanating from the various strata of the crust of the globe, and to the application of these methods to mining and underground engineering purposes, and to the general question of water supply. Such a comprehensive coordination of the whole field of research here involved, given the premises granted by the present-day physics and geophysics, leads of itself to the *systematic working out* of methods on the following principles, first laid down and substantiated by the author.[2] The collective methods of applied geophysics may be subdivided in the first place into two main groups.

In the first of these two groups we may place the processes

[2] *Jahrbuch des Halle'schen Verbandes*, III, 2, 27-46, Halle 1921; *Zeitschrift für angewandte Geophysik* 3, 3-24, 33-39, Berlin, 1922; *Umschau* 26, 529, 532, 766, 767, 1922; *idem*, 27, 55-59, Frankfort, 1923; *Das technische Blatt* 7, 50-52, 98-100, Frankfort, 1925.

based on the physical properties of those elements of the subsurface strata which are able to exert direct action at a distance. This category includes the force of gravity, the magnetic fields, and the radioactive radiations and emanations. It further includes the action of the electric potential-differences between chemically different subsurface formations, or between such formations in themselves uniform but exposed to different local chemical actions the existence and disposition of which have hitherto been indicated solely by the analysis of the electric currents excited in the Earth by these electrochemical potential-differences.

In this connection it is not necessary to deal with electrostatic forces or heat radiations, as these do not play any prominent part in actual practice. Nor is it necessary to discuss here the analysis of the rays of light emanating from the superficial deposits on the Earth's crust, or from those parts covered with transparent material (water); these factors, with geology, mineralogy, and almost all the older methods of investigation above mentioned as differing from the geophysical methods, need not be dealt with in detail here.

The second group is composed of those processes in which the constituents of the substratum, by means of their physical peculiarities, influence indirectly the development and spatial distribution of the currents of energy passing naturally through the Earth, or artificially generated in it. The structure of the substratum is revealed by the measurement of the disturbances in the normal spatial distribution of these currents caused by the lack of physical homegeneity of the Earth's surface. In this category we must place the electric, electrodynamic, geoelastic, and thermic methods of investigation. In principle, this second group also includes the influences exerted upon the radiations included in the first category, since the measurement of these radiations is influenced by the absorption taking place in the strata between the source of emanation and the place of observation. This only applies to the extent to which the special conditions connected with this absorption permit drawing conclusions as to the peculiarities of the strata absorbing the radiations. Up to the present time, no practical instance of this has been adduced.

The geophysical methods of prospecting may be divided into two categories not only with respect to their physical viewpoint, but also with respect to their *practical application*.

In many cases the physical properties of the material or special objects sought for in the substratum may themselves be utilized for the more accurate determination of the position and nature of formations. It will, however, more frequently occur that the geophysical methods of investigation will rather prove to be indirect auxiliaries towards the solution of the tectonic, geological, or structural problem in hand. This is the case when the object sought does not itself possess the physical properties exerting at a distance an action sufficiently powerful and characteristic to warrant

drawing conclusions from it. When such problems are approached with sufficient care, then genetic, tectonic, and other laws will frequently be found ruling the relations between the object sought for, though the existence of this in itself may not be physically demonstrable, and other structural elements of the lower strata possessing physical properties of such decided strength and character as to render them peculiarly suitable for investigation by means of geophysical processes based on action at a distance.

As one example out of the multitude of such possibilities for the *indirect application of geophysical methods* we may take the search for petroleum. Except in the most rare and exceptional instances, the insulating properties of the oil prevent its presence being detected physically and directly by means of electric currents. (The assertions to the contrary recently made must be decidedly rejected, as utterly failing to possess physical substantiation.)

Indirectly, however, prospecting for *oil fields* has been widely promoted and cheapened in the most various ways by geophysics. Here the general geological conditions prevailing in the region in question are naturally decisive for the choice of the special geophysical method employed. In the case of oil fields situated, as ascertained by experience already gained, on the flanks of salt masses, the position and precise limits of such salt masses, as also the depth of profile of their surface and flanks, can for instance be ascertained by means of seismic, gravity, magnetic, or electric observations. Should the oil deposits of the region concerned be situated simply on anticlinal formations, then the alternative stratification of hard and soft layers almost invariably observed in folded systems can render excellent service with the further aid of seismic methods, towards the most accurate special analysis of the folding. Should the folded systems include strata possessing comparable magnetic properties, magnetic observations may be of use. The occurrence of concentrated salt water, often found in oil fields in certain definite relations to the oil-bearing strata, can be ascertained by means of electric methods, etc. This instance, chosen at random, shows that where conditions are carefully investigated, the search for a substance in itself physically inaccessible, can be promoted to a great extent, and thus cheapened, by the indirect application of geophysical methods.

All physical and geophysical methods of investigation based on action at a distance possess the common peculiarity that every part of the substratum cooperates with every other part in acting upon every center of observation in a degree corresponding to its physical nature and its distance from this center. The propagation of the special physical action, whether this be lines of force, or radiations or currents of electric, elastic, or thermic energy, along the surface of the Earth, or in accessible places of its interior, is definitely determined by the spatial distribution of the physical properties in the substratum. Every stratum possessing definite physical properties, shown by experience to be inherent in these

ores or other formations, is bound to reveal its presence in accordance with the special laws governing its long distance action. In this sense the methods of applied geophysics thus make it possible to obtain a clear and spatially complete knowledge of the physical structure of the substratum.

One fact must, however, not be ignored, for its recognition and the careful consideration invariably accorded it in actual practice are among the prerequisites of a systematic and successful application of geophysical methods of investigation, while the overlooking of it is unfortunately only too often damaging to the cause of geophysics. This fact is that the unequivocal relations existing between the spatial distribution of the physical properties of the substratum and the formation of fields of force, radiation, or flux, on the surface of the Earth, are not simply reversible. One and the same distribution on the surface, that is, uniform results, may in principle invariably correspond to different dispositions underground, and different solutions of the geological task involved. Here the investigator must exercise the utmost care if the results of physical observations, correct in themselves, are to be correctly interpreted geologically.

Two points of view are of leading importance in this connection. While the number of mathematically possible combinations of such a series of geophysical experiments is in itself unlimited, as a matter of fact the number of interpretations is greatly restricted by the circumstances that the physical constants of the Earth's constituents, coming practically in question, are confined both qualitatively and quantitatively within fairly narrow limits. Thus the specific weight of a certain rock can scarcely exceed the value 10, electric conductivity cannot exceed a certain limit, etc., as may be seen from tables of physical constants.

Another considerable limitation upon the possibilities of the geological interpretation of the results of mathematical and physical observations lies in the general geological knowledge invariably more or less at the disposal of the investigator, from which, as experience has taught us, such conclusions can be drawn with regard to qualitative conditions as generally narrow the scope of interpretation for physical results within very small limits. It cannot be sufficiently emphasized that if a geophysical investigation is to lay claim to scientific accuracy and conscientiousness it must be preceded by a general geological observation, in order that the best adapted physical method for each case may be selected, or the most advantageous combination of various methods be made in the most suitable order. Thus in many cases where geophysical prospecting methods are applied practically, the task has already been performed to a great extent, qualitatively, by geology, and the work of the geophysicist is to discover the *quantitative* conditions of the deposit.

In Texas, for instance, a stratum of especially good conductivity at a depth of some hundred meters can only signify porous strata

permeated with highly concentrated salt water. In the mining districts, on the other hand, a mass of equal conductivity would have to be interpreted as indicating ore. In Texas a mass lacking in electric conductivity might be a salt mass or dry lime, or perhaps an oil deposit. Its exact nature can only be ascertained by measurements of the density and magnetic properties of the mass, or of the speed of the acoustic vibration possible within it.

One of the indispensable prerequisites for successful work is thus the careful selection of the methods best adapted in every respect to the special case in hand. Here not only scientific and technical considerations are to be taken into account, but at the same time those of economics and finance. The first task is to utilize all available data for ascertaining such physical properties capable of long-distance action as are possessed by the mineral (or other object) sought, and differing from those characterizing the other rocks and structural elements present in the region under investigation as clearly and unequivocally as possible, so that the object can be recognized by these characteristics. It will frequently occur that a single physical property does not suffice as unequivocally characteristic; in this case it has to be decided whether the desired object can be attained by the combination of several methods of observation, which, taken collectively, adequately characterize the substance sought. These preliminary considerations must extend to the possibility of ascertaining the position of the object sought for in the substratum, its runs and dips, its extent and thickness, and in the case of a deposit, if possible, the general lines upon which its quality is to be judged. The data are thus obtained for the development of the special methods to be applied, and for the drafting of the program of observation upon the efficient planning and execution of which the success of the undertaking so greatly depends.

The foregoing explanations may serve to show with sufficient clearness that when geophysical prospecting work of the described nature is projected, it is of prime importance to obtain the most complete possible survey of the whole field covered by applied geophysics. There is no single special process equally applicable and suitable to every category of the multiplicity of geological, mineralogical, and tectonic peculiarities of the Earth's formations. The whole sphere of applied geophysics can thus be made to comprise a uniform and complete organization; one, whose individual subdivisions cannot be separated from one another at will, for unless the possibilities and achievements of the other methods are thoroughly known, each special process can only be utilized at a great scientific and economic disadvantage.

READING BOARD FOR MAGNETOGRAPHS.

By J. M. Baldwin and W. M. Holmes.

This recording board was designed and constructed for use with the magnetograms obtained from the Eschenhagen variometer at the Toolangi Magnetic Observatory. The board is 30″x12½″x1″ and carries a straight edge *S* which can move laterally through a distance of 1 inch. When the clamping nut *C* is released *S* can be traversed by hand, the rod *R* sliding freely in a hole bored in the end of *S*. When *C* is clamped to *R*, *S* is traversed by means of the nut *N*. Upon *S* slides the set square *Q*, against the side of which runs the glass reading scale (not shown) of the same general design as that shown in "Directions for Magnetic Measurements," of the United States Coast and Geodetic Survey, (2nd Edn.), p. 108. On the lower edge of *S* is a brass bar with 25 notches spaced at 2 cm. intervals, corresponding to the distance between the hourly breaks on the magnetogram. A latch on the mounting of the set square *Q* fits into these notches, a spring serving to keep the latch in position, and *Q* pressed against the straight edge. This latch accurately locates the set square and reading scale with reference to previous settings. The magnetogram is held in position by four spring clips, and is placed in such a way that the top corner of *Q* will run along the *H* base-line when *Q* is carried along *S*. The underside of *Q* is relieved to clear the ends of the lower clips.

The daily work of changing the paper and attending to the instrument at Toolangi is carried out by a local resident, an observer from Melbourne visiting Toolangi once a month to make absolute observations and obtain scale values. Under these conditions special arrangements had to be made for the time marks. The hourly breaks are made by the clock that drives the recording drum, while at the beginning and end of each record the attendant makes an additional mark, the time of which is noted on a chronometer. The error of this chronometer is determined each month by the observer, and the assumptions are made that the rate of the driving clock is uniform for 24 hours and of the chronometer throughout the month. Experience shows that an error introduced in this way is much less than the error of scaling. From the timed marks, the values of all the time breaks on the sheet are written in. When scaling a record, the latch is put in a notch, the glass scale pressed against *Q*, and *S* then moved along until the time-scale fits in with the time-marks, so that the long vertical lines correspond to exact hours of Universal Time. *S* being clamped, *Q* can be slid along by amounts corresponding to any exact number of hours by bringing the latch into the appropriate notch.

When it is necessary to correct the position of *Q*, owing to shrinkage or expansion of the record (the hourly travel being no longer exactly 2 cms.), the slow motion may be used with advantage.

The mean ordinates to the curves for *H*, *Z* and temperature are measured in mm, but a special scale reading directly in minutes of arc, is used for *D*. Following a suggestion made by Mr. J. Shearer, late of the Watheroo Magnetic Observatory, four extra lines, two at each end, have been added to the centimeter divided into millimeters—so that the closely-divided portion runs from +0.2 cm. to −1.2 cm. This often saves a re-setting when the reading is near an exact number of centimeters. [For Fig. 1, see p. 54.]

NOTE ON A DEVICE TO FACILITATE COMPILATION OF DATA IN INVESTIGATIONAL WORK.

By C. C. Ennis.

In connection with the investigation[1] of a 27-day period in earth-currents, computers of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington have been using to great advantage a simple and easily constructed device for selecting from a list of consecutive values any values occurring at specified intervals before or after a selected date.

The method used in the treatment of this 27-day periodicity involves the selection of a number of maximum, and an equal number of minimum values of the daily ranges in the earth-current values for each month during the year. These selections having been appropriately designated, it is then necessary to select and record the values occurring on an arbitrarily chosen number of days contiguous to and centering about a period 27 days prior or subsequent to each one of the previously selected maximum and minimum values. Where there is a large mass of data to be treated in this manner, the ordinary processes of reckoning the times of these periodic recurrences are somewhat slow and laborious, and it was to facilitate and expedite this work that the device herein described was planned.

The apparatus (see Fig. 1) may be made of cardboard with the aid of a little glue or paste, and consists essentially of a groove-and-slot arrangement with appropriate scales which are made on an adding machine and pasted on the strips of cardboard on each side of the slot. The cardboard base may be extended to one side to provide for a weight thereon, as shown in the figure, in order to hold the device in position.

The consecutive values to be investigated are first listed on an adding machine, care being taken to have the spacing uniform and providing blank spaces for any days for which data are missing. It is important, in order to insure uniformity of spacing, that the two side scales be prepared on the same adding machine as used in listing the values. While one of the scales may be dispensed with, it has been found conducive to greater accuracy and speed to use the two scales. With reference to the investigation of periodicity previously mentioned, the practice has been to prepare the list of daily values for a period of one year before removing the paper from the adding machine. The paper is then inserted into the apparatus, the listed values appearing in the open slot between the two side scales. The figure "1" of the right-hand scale being placed opposite the value for the first day of the month, a daily register is thus automatically provided, and selections of the values may be made as desired, those selected being suitably marked with a cross or star as shown in the illustration and their dayes recorded

[1] By W. J. Peters and C. C. Ennis; the results will appear in the June number of this Journal.

if desirable. Any value thus chosen and designated is shifted to coincide with the "0" of the left-hand scale, and by means of this scale any subsequent value may be read and recorded as desired.

Figure 1 is a photographic reproduction of a portion of the adding-machine list of values of the daily range in earth-currents at Ebro Observatory for the year 1917 as it would appear in the apparatus. The first day of the month has been noted on the slip, and the five maximum values for the month have been designated by stars. One of these maxima (200) having been shifted to the zero of the left-hand scale, the values occurring 23 days, 24 days, etc, subsequently will be found opposite the respective numbers of the scale.

It is quite apparent that by modifying the scales, the apparatus can readily be adapted to uses other than those specified.

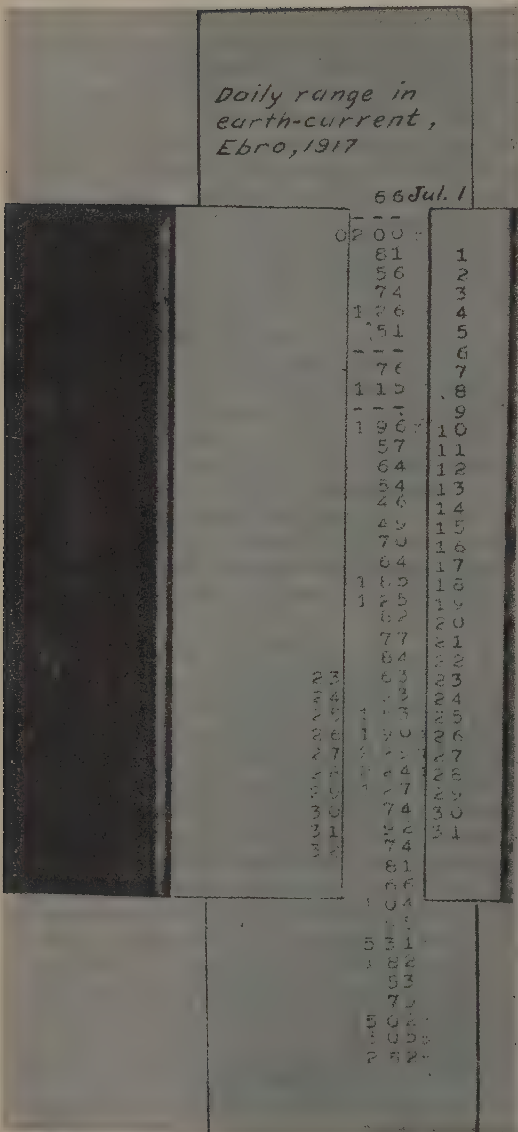


FIG. 1.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON.

ERDMAGNETISCHE BEOBACHTUNGEN AN DER WINTERSTATION DES GAUSS, 1902-03.[1]

VON JULIUS BARTELS, *Potsdam.*

1. *Einrichtung und Betrieb der Station.*—Die deutsche Südpolar-Expedition auf dem Schiffe *Gauss*, unter der Leitung von E. von Drygalski, war vom 22. Febr. 1902—8. Febr. 1903 unter 60° 2′ südl. Breite und 89° 38′ östl. Länge v. Greenw., 385 m. über dem Meeresboden, 85 Km. von der Küste entfernt, vom Eise eingeschlossen. Durch eigenartige Verhältnisse war das Eisfeld auf dem Schelf des antarktischen Kontinents fast vollständig fest verankert, sodass es, wenn auch unter erheblichen Schwierigkeiten, dem Physiker der Expedition, Fr. Bidlingmaier[2], möglich war, ein vollständiges magnetisches Observatorium 10 Monate (April 1902—Januar 1903) in vollem Betrieb zu erhalten. Zwei aus grossen Eisquadern auf einer Scholle erbaute Häuser dienten bis Anfang Juli 1902 für die Variationsbeobachtungen und absoluten Messungen, bis die von den Stürmen angehäuften Schneewehen die Häuser begruben und die Scholle unter der Schneelast allmählich unterging. Deshalb wurde Anfang Juli die Station in 2 Grotten eines Eisberges verlegt; hier wurde der Betrieb durch Schmelzwasser erschwert, das im Sommer von oben eindrang. Gemeinsam waren beiden Stationen die Schwierigkeiten, die durch Schwankungen des Eisfeldes in Azimut und Niveau hervorgerufen wurden.

Bei den absoluten Messungen, die infolge der grossen magnetischen Unruhe stets mehrere Stunden erforderten, ging die Temperatur im Winter bis unter −20° hinab; äusserst günstig waren dagegen in der ganzen Zeit die geringen Temperaturschwankungen im Variationsraum mit einer täglichen Maximalamplitude von 0.°2—0.°3 Celsius. Zur absoluten Messung von D und H diente ein Stationstheodolit Tesdorf, von I ein Erdinduktor Schulze; die Konstanten wurden vor und nach der Reise in Potsdam bestimmt. Die Variationsinstrumente sind von demselben Typ

[1]Kurzer Auszug aus dem bereits erschienenen Werk: FR. BIDLINGMAIER, Erg. d. erdmagn. Variationsbeob. a. d. Gauss-Station in der Antarktis 1902-03. (Deutsche Südpolar-Expedition auf dem Schiffe *Gauss*, herausgeg. von E. VON DRYGALSKI, Band VI, Heft 4), dessen Vollendung nach dem Tode *Bidlingmaiers* dem Verfasser und seinem Bruder *Fritz B.* übertragen wurde. Die gedruckt vorliegenden, auf Erdmagnetismus bezüglichen Teile des Expeditionswerkes sind (in Klammern: Ort der Besprechung in *Terr. Mag.*): *Band V:* FR. BIDLINGMAIER: 1. Der Doppelkompass, seine Theorie und seine Praxis; 2. Erdmagnetische Seebeobachtungen, Teil I: Die Grundlagen; 3. Teil II: Deklination [XVI, 1911, S. 251], 4. Teil III, P. NELLE, Inklination; 5. Teil IV, P. NELLE, Horizontal Intensität; 6. Teil V, J. BARTELS, *a* Total-Intensität, *b*. Die Beobachtungen an Land-Stationen, *c*. Einzelheiten über die Inklinations-Messungen. *Band, VI*, Heft 1-3: K. LUYKEN: Die erdmagn. Ergebnisse der Kerguelen-Station 1901-03 [XI, 1906, S. 202; XIV, 1909, S. 87]; *Atlas II* [XVIII, 1913, S. 84].—Vorläufige Berichte, "*Veröffentlichungen des Instituts für Meereskunde*, Berlin," Heft 1, 2, 4 (1902-03). Vergleiche auch *Terr. Mag.* VI, 1901, S. 57; VII, 1902, S. 5; XVII, 1912, S. 145.

[2]Biographie Terr. Mag. XX, 1915, S. 130.

wie die auf Kerguelen benutzten und sind von Luyken (l. c) beschrieben. Durchschnittliche Skalenwerte pro mm.: $\triangle D = 1' = 4\,\gamma$, $\triangle H = 3\,\gamma$ (etwas zu empfindlich für die Antarktis: häufiges Umschlagen des Magneten am Intensitäts-Unifilar), $\triangle Z = 7\,\gamma$. Der zu schwache Deklinationsmagnet machte die Torsionsbestimmung bei den absoluten D-Messungen unsicher; diese Sorge wurde durch die Untersuchung *Terr. Mag.* IX, 1904, S. 157 behoben[3]. Bidlingmaier war unter der Last des überaus anstrengenden Beobachtungsdienstes erst im Oktober 1902 auf diese drohende Fehlerquelle aufmerksam geworden; er rät deshalb künftigen Genossen: "lieber weniger beobachten, aber sich dauernd durch ganz einfache vorläufige Ueberschlagsrechnungen auf dem Laufenden erhalten!"

2. *Die Ergebnisse.*—In Anbetracht der seltenen Lage der Gauss-Station in der Antarktis und auf dem Meere ist das gesamte Kurvenmaterial, mit dem Adolf. Schmidt'schen Pantographen auf einheitlichen Massstab umgezeichnet, in dem Atlas reproduziert. Das neue Heft bringt ferner Stundenmittelwerte von D, H und Z mit einer eigentümlichen, 4-Stufen umfassenden Darstellung der Unruhe eines jeden Stundenintervalls.

Die endgültigen Mittelwerte für die 10 Monate März 1902—Januar 1903 (etwa 260 Tage lückenloser Registrierungen; bei Z fehlt der März 1902) sind:

$H = 13311\gamma$; $D = 62°\ 23'$ W; $I = -77°\ 07.'2$; $F = 59709\gamma$;

X (Nordkomp.) $= 6176\gamma$; Y (Ostkomp.) $= -21794\gamma$; Z (Nadirkomp.) $= -58206\gamma$. Das Mittel der je 5 ruhigen Tage im Monat unterscheidet sich nur bei Z systematisch von dem aller Tage: der absolute Wert von Z ist, wie in mittleren Breiten, an ruhigen Tagen kleiner (um 5γ).

Jährlicher und säkularer Gang sind infolge der Kürze der Beobachtungszeit nicht zu trennen. Auffallend ist ein starker einseitiger Gang in den Monatsmittelwerten: In den 10 Monaten nimmt D um etwa 10′ ab, H um 66γ zu, Z um etwa 30γ ab. Die Zuverlässigkeit der Messungen, die sich in den geringen mittleren Fehlern der Basiswerte ausdrückt ($D, \pm 3'$; $H, \pm 3\gamma$; $Z, \pm 20\gamma$), lässt an der Realität dieses Ganges nicht zweifeln; dafür spricht auch der Umstand, dass sich H und Z in *entgegengesetztem* Sinne ändern, während eine durch Unsicherheit der Basiswerte vorgetäuschte Änderung in beiden Elementen gleichsinnig verlaufen müsste[4]. Die Erscheinung ist mit einer *Bewegung des magnetischen Südpols von der Station fort, also etwa nach Ost-Süd-Ost,* zu erklären. Zur Gewissheit wird diese Vermutung durch einen Vergleich mit den gleichzeitigen H=Registrierungen an der Kerguelen-Station (49° 25′S, 69° 53′ E. v. Gr.) und zu Batavia; letztere Station zeigt, dass es sich nicht etwa um eine Änderung des Momentes der Erde handeln kann:

[3]Vergleiche den Zusatz *Terr. Mag.* X, 1905, S. 51.

[4]Nach einem Hinweis von Prof. ADOLF SCHMIDT.

Abweichungen der Monatsmittel von H vom Durchschnitt der 10 Monate April 1902—Januar 1903.

Monat	Apr.	Mai	Juni	Juli	Aug.	Sept.	Okt.	Nov.	Dez.	Jan.	Mittel
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	
Gaus-St. . .	−30	−31	−23	− 2	0	+ 2	+ 7	+19	+22	+36	13310 γ
Kerguelen.	−20	−12	− 6	− 6	− 2	+ 2	+ 5	+ 6	+14	+16	16245 γ
Batavia. . .	+ 3	+ 5	+ 3	+ 3	0	− 2	0	− 5	− 2	− 5	36707 γ

Der Korrelationsfaktor zwischen den H—Werten an der Gauss- und der Kerguelen-Station erreicht den hohen Wert von +0.95 (wahrscheinlicher Fehler 0.02); das bedeutet zugleich eine *glänzend bestandene Probe auf die Präzision der Messungen* an den beiden Stationen der deutschen Südpolar-Expedition trotz aller Schwierigkeiten. Um die Grössenordnung der Bewegung zu schätzen, kann man den lokalen Gradienten der Horizontalintensität benutzen und findet, dass einer Änderung von H auf Kerguelen um 100γ eine Wanderung des Südpols um 44 Km. entspricht, was für hier beobachtete Änderung um 36γ auf rund 16 Km. in 10 Monaten führt, d. h. etwa 0.°6 Länge pro Jahr[5]. Die Ost-Richtung der Verschiebung bestätigt eine Vermutung von Chree[6], wonach die grossen Sprünge in den Basiswerten D an der Discovery-Station, die auf eine Westwanderung führen würden, auf instrumentellen Fehlerquellen oder lokalen Störungen beruhen.

Der *tägliche Gang* von D, H, I, X, Y, Z wurde für alle und für die je 5 ruhigen Tage berechnet. Die gleichmässig minimalen Sonnenflecken-Relativzahlen während der ganzen Beobachtungszeit liessen es gerechtfertigt erscheinen, zwecks Berechnung zuverlässiger Tertial- und Jahresmittel den täglichen Gang der beiden fehlenden Monate zwischen Anfang und Ende der Reihe zu *interpolieren*. Ich ging dabei aus von den harmonischen Konstanten p_n, q_n der $\frac{1}{n}$—tägigen Welle ($p_n \cos n\,t + q_n \sin n\,t$) für die beobachteten Monate; sie wurden als rechtwinklige Koordinaten (Komponenten des Schwingungsvektors) in ein Diagramm eingetragen. Auf der freihändig gezogenen Verbindungslinie der Endpunkte der Schwingungsvektoren werden dann die den fehlenden Monaten entsprechenden Punkte gewählt und aus den so bestimmten harmonischen Konstanten die täglichen Gänge berechnet. In allen Elementen erscheinen je *zwei* tägliche Maxima und Minima; charakteristisch ist ein starkes Maximum von D (+10.′5 im Jahresmittel) um 9.^{h}5 vormittags. Die periodische tägliche Amplitude zeigt, ebenso wie die unperiodische, einen starken jährlichen Gang in Gestalt einer einfachen Welle mit dem

[5] Uber die Lage des magnetischen Südpols vergl. *Terr. Mag.* XIV, 1909, S. 85-86.

[6] Nat. Antarctic Exp. 1901-04, Mag. Obs., London (Roy. Soc.) 1909, S. 81; British (Terra Nova) Antarctic Exp. 1910-13, *Terr. Mag.*, London, 1921, S. 44

Maximum im Süd-Solstitium; die auf Kerguelen noch erkennbaren Äquinoktial-Maxima sind gänzlich verschwunden.

Aus der Unsymmetrie der täglichen Maxima und Minima in Bezug auf das Monatsmittel geht hervor, dass die unperiodischen Änderungen die Tendenz haben, stundenweise *Z* anormal zu erhöhen, *H* anormal zu erniedrigen, ähnlich wie in mittleren Breiten. Hinsichtlich des *Störungscharakters* müssen Sommer- und Winterkurven unterschieden werden: Im Sommer herrscht fortwährende Unruhe mit grossen, welligen Zügen; im Winter dagegen kommen die Störungen—besonders typisch um Mitternacht—aus der Ruhe heraus in heftigen, raschen Bewegungen zum Ausbruch. In einem magnetischen Wintersturm erreicht die maximale Schwankung in Deklination 1 bis 1½°, in Horizontalintensität 300 bis 400γ, in Vertikalintensität 600 bis 800γ, während sie im Sommersturm zu den doppelten Werten ansteigen kann. Die im Laufe der 10 Monate registrierten höchsten und tiefsten Stundenmittel unterscheiden sich bei *D* um 2°, *H* um 400γ, Z um 950γ.

Gelegentlich einer der Schlittenreisen zum Festland wurde am *Gaussberg* ein Variations-Observatorium eingerichtet und für 90 Stunden brauchbare Kurven für *D* und *H* erzielt, die in den grossen Zügen mit den gleichzeitigen Kurven der Winterstation übereinstimmen.—Die *Terminstunden* sind auch an der Gauss-Station durchweg ruhig verlaufen; die betreffenden Feinregistrierungen finden sich am Schlusse des Atlas.

PROVISIONAL SUNSPOT NUMBERS FOR JANUARY TO MARCH, 1926.

By A. Wolfer.

Day	Jan.	Feb.	Mar.	Day	Jan.	Feb.	Mar.
1	93	..	...	17	94	..	79
2	..	42	68	18	...	85	70
3	60	38	103	19	...	..	69
4	37	41	103	20	...	67	46
5	..	34	119	21	103	59	38
6	56	29	...	22	...	41	..
7	52	35	100	23	102	48	..
8	76	44	...	24	...	49	35
9	90	..	82	25	124	64	37
10	92	..	63	26	...	..	45
11	84	99	47	27	78	53	45?
12	69	97?	...	28	40?	..	17?
13	57	142	45	29			30
14	55	150	58	30	48		31
15	..	162	89	31	21		..
16	..	...	107				
				Mean for month	71.6	69.0	63.6

Zürich, March 31, 1926.

MAGNETIC OBSERVATIONS BY THE SWISS EXPEDITION TO GREENLAND 1912-1913.[1]

By Paul L. Mercanton.

Abstract.

Observations of the *declination*, *D*, were to serve especially to determine the route to be followed. It was sufficient to determine it to 0°.1. Besides since variations, or disturbances, may be of the order of a degree, or more, and as the Expedition could not refer its observations to a base station, more precise observations would have been illusory. The observations were made by means of solar azimuths taken with the portable Hildebrand theodolite and excellent chronometers. The magnetic azimuths were read on the compass accompanying the theodolite, the needle of which was 6 cm. in length. The declinations may be regarded as accurate to about 0°.1. The compass was compared at Rude Skov, near Copenhagen.

The *inclination*, *I*, was measured by the means of a needle 10 cm. in length, enclosed in a special box adjustable to the same theodolite, and carefully mounted on jewels. A certain number of readings were made in the plane of the magnetic meridian by reversing the needle. When all the corrections are applied, an approximation of 3′ may be counted on.

The following table contains all the observations obtained that are deemed worthy of publication.

Table 1.—*Results of magnetic observations in Greenland in 1912-1913.*

Date 1912–13	Station	Lat.	Long.	Alt. Above S. L.	Mag. El. *D*	Mag. El. *I*	Loc. Mean Time	Nature of Soil
		° ′	° ′	m.	°	°		
Jun. 8–9	Jakobshavn	69 13.1	51 06.0	5	....	81.75	......	....
" 11	Q-havn	69 45.3	50 15.0	5	62.1	81.5	......	....
" 21	Camp 1	69 41.1	....	789	60.0	81.45	......	....
" 22	" 2	69 38.6	49 37.2	979	61.0	.....	......	....
" 23	" 3	69 35.4	....	1120	59.1	.....	......	....
" 29	" 9	(69 08.0)	47 25.0	1641	57.1	.....	......	....
Jul. 3	" 12	68 49.2	46 12.2	1888	54.2	.....	......	....
" 4	" 13	68 41.2	45 44.2	1936	53.1	.....	......	....
" 5	" 14	68 34.0	45 16.1	2046	54.1	80.6	......	....
" 6	" 15	....	....	2176	....	80.55	......	....
" 7	" 16	68 15.1	....	2243	53.0	80.4	......	....
" 8	" 16	....	44 15.1	......	....	.....	......	....
" 9	" 17	(68 06.0)	....	2318	54.0	80.3	......	....
" 10	" 18	(67 54.0)	(43 15.0)	2399	52.1	80.2	......	....
" 10	" 19	(67 42.0)	....	2457	51.2	80.1	......	....
" 12	" 20	....	....	2491	52.1	79.9	......	....
" 13	" 21	....	....	2501	51.1	79.9	......	....
" 14	" 22	(67 16.0)	41 34.0	2432	50.1	79.95	......	....
" 15	" 23	67 04.6	....	2258	50.1	.....	......	....
" 16	" 24	(66 58.1)	40 52.1	2254	50.0	79.8	......	....

[1] Résultats scientifiques de l'Expédition suisse au Groenland 1912-13. Par A. de Quervain, P.-L. Mercanton, etc. Mém. Soc. Helvétique Sci. nat., et Meddelelser om Groenland. (In press.)

Date 1912–13		Station	Lat. °	′	Long. °	′	Alt. Above S. L. m	Mag. El. D °	Mag. El. I °	Loc. Mean Time		Nature of Soil
Jul.	17	Camp 25..........	66	46.8	40	21.2	2084	48.1	.....	......		....
"	18	" 26..........	66	30.0	39	43.2	1816	50.0	79.1	......		....
"	19	" 27..........	66	14.8	(38	58.1)	1465	48.1	.....	......		....
"	20	" 28..........	66	04.3	38	27.6	1236	47.1	.....	......		....
"	21	" 29..........	66	01.8	(38	12.1)	822	49.0	79.0	......		....
"	30	Depot, east coast...	65	55.3	37	52.1	36	47.0	78.6	......		....
Aug.	6	Angmagsalik.......	65	36.6	37	33.1	32	43.0	.....	......		....
Sep.	8	Godthaab.....(M)[1]	64	10	51	49	10	....	79.4	14	45	gneiss
May	23	Holstensborg...(M)[1]	....		....		......	....	81.55	20	40	glacier
"	26	" (M and Q)[1]	66	56	53	47	40	....	81.55	13	15	over gneiss
"	27	".......(M)[1]	....		....		......	....	81.65	21	45	....
		Mean	....		....		......	....	81.6	......		....
Jun.	6	Egedesminde...(M)[1]	68	42	52	52	10	....	81.95	23	15	gneiss
Sep.	6	Godhavn......(M)[1]	69	14	53	32	10	....	81.5	8	45	"
Jun.	8	Jakobshavn....(M)[1]	69	11	51	05	90	....	81.85	20	15	"
Aug.	25	" (M)[1]	69	13	51	05	30	....	81.75	14	45	"
"	20	Atâ de l' Ikerasak (Arve-Prinsen-Oe)	69	44	50	49	10	....	81.85	19	00	"
Jun.	12	Port-Quervain (M)[1]	69	45	......		2	....	81.55	20	45	"
"	21	Inlandsis 1....(M)[1]	69	41	49	56	789	....	81.45	......		ice
Jul.	5	" 14....(Q)[1]	68	34	45	16	2046	....	80.6	......		"
"	6	" 15....(F)[1]	68	25	44	47	2176	....	80.55	......		"
"	7	" 16 "	68	15	44	16	2243	....	80.4	......		"
"	9	" 17 "	68	06	43	49	2318	....	80.3	......		"
"	10	" 18 "	67	54	43	15	2399	....	80.2	......		"
"	10	" 19 "	67	42	42	42	2457	....	80.1	......		"
"	12	" 20 "	67	32	42	16	2491	....	79.9	......		"
"	13	" 21 "	67	23	41	54	2501	....	79.9	......		"
"	14	" 22 "	67	16	41	34	2432	....	79.95	......		"
"	16	" 24 "	66	58	40	52	2254	....	79.8	......		"
"	18	" 26 "	66	30	39	44	1816	....	79.1	......		"
"	21	Lisière (Edge)	66	02	38	13	822	....	79.0	......		moraine
"	30	Depot 30..........	65	55	37	53	36	....	78.6	......		gneiss

[1]Q=de Quervain; M=Mercanton; F=Fick.

Additional remarks for the stations occupied by P. L. Mercanton on the west coast of Greenland:

Godthaab—gneiss, peninsula where ships are moored.
Holstensborg—sandy over gneiss, near the house of the doctor.
Egedesminde—gneiss, 20 meters east of the church (of wood).
Godhavn—gneiss, 50 meters from the sea, south of house of the "bestyrer."
Atâ de l' Ikerasak (*Arve-Prinsen-Oe*)—gneiss, on the seashore, 50 meters from the house of the "Forstaender," Pavia Jensen.
Port Quervain—gneiss, on the seashore.

SERVICE MÉTÉOROLOGIQUE
LAUSANNE, SWITZERLAND.

SUMMARY OF THE CHIEF MAGNETIC RESULTS OF THE GJÖA EXPEDITION, 1903-06[1].

By Nils Russeltvedt and Aage Graarud.

The following explanatory information may be given for Tables I-IX:

On his way to Gjöahavn, Captain Roald Amundsen made magnetic observations at the two stations, Godhavn and Beechey Island. During the stay at Gjöahavn the immediate neighborhood of the base-station was closely surveyed. The mean values of the magnetic elements at these stations (Nos. 1-13) will be found in Table VIII. Near the Magnetic North Pole, Amundsen observed at three stations, Nos. II, III and IV; however, the region between 69°N and 70°N is represented by but a single station, No. I. The geographic positions of the stations and of the Magnetic North Pole are shown in Figure 1.

The data given in Table VIII are reduced so that they correspond in time to the mean values for Gjöahavn, given in the fifteenth row of Table II. *We may thus say that the data given in Table VIII refer to the epoch 1904.5.* Photographic registrations of the magenetic variations were obtained at Gjöahavn during 19 months and at King Point 6 months.

Table I.—*Showing the number of determinations of the magnetic elements at the stations given in Table VI.*

Sta.	*D*	*H*	*I*	*F*	Sta.	*D*	*H*	*I*	*F*	Sta.	*D*	*H*	*I*	*F*
I	3	12	5	1	1	6	30	3	1	7	32	42	0	0
II	2	12	4	1	2	16	60	0	0	8	4	20	0	0
III	0	0	2	0	3	11	34	0	0	9	3	18	0	0
IV	2	10	4	1	4	5	24	0	0	10	2	14	0	0
					5	6	24	0	0	11	6	14	0	0
					6	7	24	0	0	12	3	14	0	0
										13	4	14	0	0

From Table I it will be seen that there have been collected large series of data at most of the stations. Thus a reduction to the chosen epoch, 1904.5, could be attempted with comparatively satisfactory results. (*D* stands for the magnetic declination, *I*, for the inclination, and *H*, *Z*, *F*, for the horizontal, vertical and total intensity, respectively.)

For Gjöahavn, as well as for the stations in Table VIII, the geographic rectangular components (*X* plus towards North, and *Y* plus towards East) were computed by aid of the usual formulae.

Considering magnetic charts there are two important questions awaiting answer:

1. Geographic coordinates for the mean Magnetic North Pole;
2. Periodic and aperiodic movements of the Magnetic North Pole.

[1] Extracted, with some revisions, from "Die Erdmagnetischen Beobachtungen der Gjöa-Expedition, 1903-1906." Vorläufige Mitteilung. *Geofysiske Publikationer*, vol. III, No. 8, pp. 1-14, Oslo, 1925.

As to the second question, some idea of the periodic movement may be obtained from the data given in Tables VI and VII. Furthermore as regards the possible aperiodic movement of the magnetic pole it will be of interest to state that it sometimes happened, that the variometer at Gjöahavn indicated values corresponding to $H=0$; the maximum value of the horizontal intensity registered amounted to 0.013 C. G. S. It will also be of interest to give the extreme values of the magnetic declination registered at Gjöahavn, namely:

Maximum west declination 126°; maximum east declination 57°.

Regarding the first question, as to geographic coordinates for the mean position of the Magnetic North Pole, it will be appreciated that because of the paucity of the stations about the pole a satis-

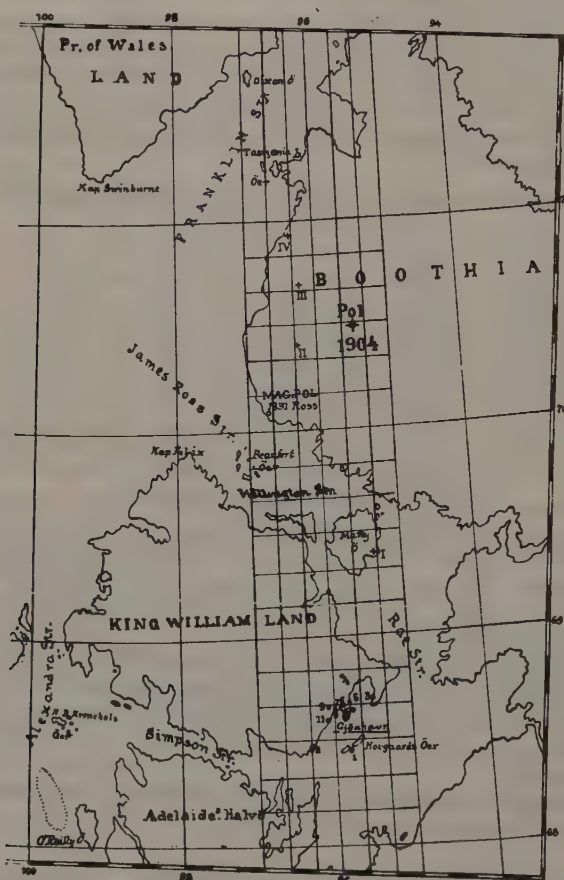


Fig. 1.

factory answer as to accurate coordinates would be difficult to give. We may however remark that the Gjöa-material offers several good hints for an approximate location of the pole. In the first place we can state, that the values for X and Y for station IV show *that increasing values for Gjöahavn do correspond to decreasing values at Station IV*, from which fact we conclude that the mean pole is situated south of the latter station. Secondly, we may state that Station III was so near the pole, that no observations for H could be completed; the most probable mean direction of the declination has however been given by Amundsen.

If, therefore, we should hazard approximate coordinates for the mean position of the Magnetic North Pole in 1904 we might propose:

$$\phi = 70° \, 30' \mathrm{N}; \; \lambda = 95° \, 30' \mathrm{W}$$

Besides Tables I-VI, which have already been explained, we have collected in Table VII some magnetic data for seven important Arctic stations. The magnetic data in this table, as well as those obtained on the second "Fram-Expedition," are all of them based on magnets IV and V of the Zschau magnetic apparatus.

TABLE II.—*Monthly means of the magnetic elements at Gjöahavn.*

(Lat., 68°37′14″N; Long., 95°53′25″W.)

Year	Month	D (West)	I	H	Z
		° ′	° ′	c. g. s	c. g. s.
1903	Nov.	9 40	89 17.8	0.00744	0.60503
	Dec.	8 05	18.4	732	474
1904	Jan.	8 40	18.1	737	486
	Feb.	8 55	17.4	750	473
	Mar.	8 10	16.9	758	466
	Apr.	7 55	16.9	758	476
	May	7 40	16.5	765	461
	Jun.	7 00	16.0	774	458
	Jul.	6 35	15.6	781	468
	Aug.	6 10	16.3	769	458
	Sep.	6 30	16.6	764	450
	Oct.	6 40	16.6	764	464
	Nov.	6 55	17.0	755	462
	Dec.	6 55	17.0	755	435
Mean	(1904.5)	7 21	89 16.7	0.00761	0.60463
1905	Jan.	6 55	89 17.4	0.00749	0.60429
	Feb.	7 20	17.7	743	441
	Mar.	5 20	17.3	751	437
	Apr.	5 50	17.7	745	439
	May	5 05	16.6	763	424

TABLE III.—*Monthly means of the magnetic elements at King Point.*
(Lat., 69°06′N; Long., 138°08′W.)

Year	Month	*D* (East)	*I* (North)	*H*	*Z*
		° ′	° ′	*c. g. s*	*c. g. s.*
1905	Oct.	42 26	81 51.3	0.08451	0.59051
	Nov.	28	52.6	435	074
	Dec.	25	51.8	445	065
1906	Jan.	23	51.1	456	062
	Feb.	25	51.8	444	060
	Mar.	24	50.8	460	052
	Mean	42 25	81 51.6	0.08448	0.59061

TABLE IV.—*Monthly means of the ranges of the magnetic elements at Gjöahavn.*

Month	1903			1904			1905		
	D	*H*	*Z*	*D*	*H*	*Z*	*D*	*H*	*Z*
	°	γ	γ	°	γ	γ	°	γ	γ
Jan.	....	...	...	28.0	206	211	13.0	137	157
Feb.	....	...	...	22.0	202	212	20.4	235	270
Mar.	....	...	...	11.2	156	101	20.0	248	270
Apr.	....	...	...	18.9	260	240	22.2	267	284
May	....	...	...	21.7	293	319	19.0	273	292
Jun.	....	...	...	19.8	248	299	....	...	...
July	....	...	...	19.9	290	206	....	...	...
Aug.	....	...	...	18.5	225	175	....	...	...
Sept.	....	...	...	13.8	192	169	....	...	...
Oct.	....	...	...	16.3	158	198	....	...	...
Nov.	27.0	218	237	14.7	146	170	....	...	...
Dec.	12.7	225	140	9.0	116	118	....	...	...
Mean	....	...	...	17.8	208	202	....	...	...

TABLE V.—*Monthly means of the ranges of the magnetic elements at King Point.*

Year	Month	*D*	*H*	*Z*
		′	γ	γ
1905	Oct.	101	388	337
	Nov.	173	630	512
	Dec.	94	373	289
1906	Jan.	79	324	244
	Feb.	172	629	475
	Mar.	121	501	396

TABLE VI.—*Diurnal variation of D and H at Gjöahavn for mean of year 1904.*
(A plus sign means motion of north end of magnetic needle towards west, and increase of H.)

El.	G. M. T.	1	2	3	4	5	6	7	8	8	10	11	12
		°	°	°	°	°	°	°	°	°	°	°	°
D	A. M.	+2.5	+2.8	+2.7	+2.7	+2.6	+2.3	+1.6	+1.1	+0.2	−0.5	−1.0	−1.4
	P. M.	−2.1	−2.7	−3.1	−3.4	−3.2	−2.7	−2.1	−1.0	−0.1	+0.9	+1.6	+2.2
			γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
H	A. M.	−16.1	−10.6	−5.6	−1.3	+2.4	+10.4	+17.6	+19.9	+22.8	+22.3	+22.4	+22.9
	P. M.	+20.1	+15.6	+7.2	−2.3	−8.2	−11.4	−11.1	−18.8	−24.9	−28.5	−24.6	−20.1

TABLE VII.—*Annual variation of D and H at Gjöahavn for 1904.*

El.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
	′	′	′	′	′	′	′	′	′	′	′	′
D	+32	+55	+19	+13	+6	−25	−41	−57	−28	−10	+14	+23
	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ	γ
H	−18	−6	+1	0	+6	+14	+20	+7	+1	0	−10	−11

TABLE VIII.—*Magnetic data for the field-stations in the neighborhood of the Magnetic North Pole, reduced to the epoch, 1904.5.*

Sta.	φ(North)	λ(West)	*D*	*I*	*X*	*Y*	*H*	*F*
	° ′	° ′	°	° ′	*c. g. s.*	*c. g. s.*	*c. g. s.*	*c. g. s.*
I	69 23.7	95 21.8	35.5W	89 36	+0.00336	−0.00240	0.00410	0.60885
II	70 25.2	96 18.0	45.7E	34	+ 281	+ 288	395	0.61065
III	70 42.1	96 15.0	120.0E[2]	52	....	....	140[2]	....
IV	70 55.1	96 21.0	101.5W	38	− 057	− 280	285	0.60540
1	68 26.9	95 49.0	44.0E	15	+ 543	+ 523	755	0.60800
2	68 28.4	96 18.2	2.8E	.....	+ 899	+ 047	900	....
3	68 42.2	95 30.7	35.2E	.....	+ 527	+ 372	645	....
4	68 48.1	95 55.5	4.2W	.....	+ 653	− 048	655	....
5	68 40.8	95 54.2	19.2W	.....	+ 711	− 248	755	....
6	68 39.8	95 52.6	13.2W	.....	+ 712	− 167	730	....
7	68 38.3	95 53.4	14.3W	.....	+ 761	− 193	785	....
8	68 38.3	95 59.2	17.8W	.....	+ 667	− 215	715	....
9	68 39.5	96 02.4	25.7W	.....	+ 603	− 290	670	....
10	68 37.7	95 52.7	10.2W	.....	+ 766	− 139	780	....
11	68 36.1	96 02.5	5.5E	.....	+ 794	+ 077	800	....
12	68 37.0	95 53.8	9.0W	.....	+ 793	− 126	805	....
13	68 37.2	95 51.2	2.0W	.....	+ 723	− 037	725	....

[2] Value estimated according to information given by Capt. Amundsen.

TABLE IX.—*Magnetic data for some Arctic stations (Fram II and Gjöa.).*

Station	Expedition	Year	φ(North)	λ(West)	*D*	*I*	*H*
			° ′	° ′	°	° ′	*c. g. s.*
Rice Strait....	Sverdrup	1899.2	78 46	74 57	103.0W	86 00.0	0.04030
Havne Fjord...	"	1900.5	76 29	84 04	116.7W	87 01.0	3320
Gaase Fjord...	"	1901.6	76 49	88 40	129.6W	87 41.0	2520
Godhavn......	Amundsen	1903.6	69 14	53 24	62.5W	81 50.0	8210
Beechey Island.	"	1903.7	74 43	91 54	128.5W	88 30.0	1550[3]
Gjöahavn.....	"	1904.5	68 37	95 53	7.4W	89 16.7	0760
King Point....	"	1906.0	69 06	138 08	42.4E	81 51.6	8450

[3] Value for *H* calculated from observed data for *I* and *F*.

LETTERS TO EDITOR

PRINCIPAL MAGNETIC STORMS AND EARTHQUAKES AT THE WATHEROO MAGNETIC OBSERVATORY, OCTOBER TO DECEMBER 1925.

(Lat., 30° 19′.1 S.; Long., 115° 52′.6 or 7^h 44^m E. of Greenwich.)

Greenwich mean time						Range		
Beginning			Ending			Decl'n	Hor. int.	Vert. int.
1925	*h*	*m*	*d*	*h*	*m*	′	γ	γ
Oct. 21	6	46	25	0	19	....	157	...
Oct. 21	6	49	25	0	19	19.7	...	...
Oct. 21	6	50	25	0	19	....	...	120
Dec. 27	14	48	28	19	01	....	166	...
Dec. 27	14	49	28	19	02	14.7	...	155

October 21-25, 1925. This protracted disturbance of moderate severity is the only one tabulated as a magnetic storm during October though the month as a whole was greatly disturbed. The storm was characterized by bays and peaks, the most prominent of which occurred on October 21 at 14^h.2 and 19^h.8, on October 22 at 14^h.5 and 19^h.7, and on October 24 at 8^h.2. At 8^h on October 24 there was quite a violent disturbance in vertical intensity, causing a change of 80γ in 17 minutes; the disturbance in horizontal intensity was not marked, and the declination changed 13′ westward in the same period.

December 27-28, 1925. This comparatively mild storm began suddenly and practically simultaneously in all three elements. Following the preliminary oscillations, there was a slight disturbance in all three curves at 20^h on December 27. The maximum disturbances occurred on December 28 between 6^h and 14^h. The magnetic records for December were mildly disturbed throughout.

There were no *earthquake records* on the magnetograms at Watheroo for the last quarter of 1925.

All times given are Greenwich civil mean time.

H. F. Johnston, *Observer-in-Charge.*

PRINCIPAL MAGNETIC STORMS AND EARTHQUAKES, JANUARY 1926, AT THE WATHEROO MAGNETIC OBSERVATORY WITH NOTES REGARDING AURORA AND CABLE AND RADIO DISTURBANCES.

January 22-23, 1926.—This storm, though not of great severity, was characterized by a sudden commencement about 15^h36^m from previously very steady conditions. On the horizontal-intensity trace, where the commencement was most marked, the change amounted to 54 gammas, if the commencement be regarded as being a sudden increase of the horizontal-intensity ordinate. However, it is possible that the beginning was a very rapid downward movement, followed by a more leisurely upward trend, since there is a slight darkening of the paper immediately under the point of commencement. In this event the change amounted to 63 gammas in slightly less than 5 minutes, as contrasted with 54 gammas given by the first possibility. The disturbance as a whole was marked by frequent and rapid changes though not of exceptional range.

January 26-29, 1926.—Slightly disturbed conditions prevailed before the beginning of this storm, the beginning of which is placed at the point where the traces begin to evidence more rapid perturbations. No great departure from the mean occurred until 16^h17^m January 26 when the horizontal intensity increased by 72 gammas in a single minute. Simultaneously, in the same period, declination and vertical intensity decreased by 5.4 minutes and 14 gammas, respectively. Until 1^h01^m January 27, violent oscillations of all three elements took place, the horizontal-intensity curve meanwhile, after the rapid preliminary upward movement, sweeping right across the sheet, till shortly after Greenwich midnight it was almost as far below its base-line as formerly it had been above it.

Less violent changes occurred after 1^h on January 27 though the most pronounced phase of the disturbance continued till 2^h05^m. The elements then settled down to more steady values though they were by no means normal for horizontal-intensity values. Indeed, normal conditions can hardly be said to have been regained by the end of the month. Horizontal-intensity values were exceptionally low till January 31 and the end of the disturbance has been tentatively placed at 17^h06^m January 29. The major portion of the disturbance was of comparatively short duration though it was of exceptional severity.

Aurora and cable and radio disturbances—On the night of January 27 a faint aurora was reported by Professor A. D. Ross as visible at Albany, Western Australia, in latitude 35 degrees south and is described in the following excerpt from his letter of January 29, 1926 (times being Greenwich mean time, civil reckoning):

"Your telegram regarding the magnetic storm of the 27th instant was received here at midday. As the moon was nearly full that

night there did not seem much hope of seeing an aurora unless it was unusually bright for these latitudes. In the evening after sunset the sky was partially obscured by numerous cirro-cumulus clouds and, with the rapidly falling temperature and southerly wind, a thin veil of mist diminished visibility through the cloud gaps. About 13^h30^m seeing conditions improved, and I kept a lookout from the Fort Hill which forms the eastern extremity of Mount Clarence. Shortly before 14^h the sky near the southern horizon appeared distinctly brighter than in other directions. The boundary of the glow was very ill-defined, but I estimated that the glow extended along the horizon about 25 to 30 degrees east and west of the south point. It attained its greatest height almost due south (perhaps slightly to the west of south), the altitude there being 15 to 18 degrees at most. I felt in considerable doubt as to whether this glow was auroral and was not merely an effect due to the moonlight coming from the northern sky and illuminating slight haze. At no time was the whole region referred to completely free from cloud, small fleecy patches of light cumulus coming up constantly from the south. The glow was very pale in color but of a bluish tinge. But for your telegram I should not have taken notice of it, and certainly should not have regarded it of an auroral nature. On the other hand, it appeared to diminish rapidly in intensity between 14^h40^m and 14^h50^m and by 15^h could hardly be detected. This diminution of apparent intensity was unaccompanied by any observed change in the amount of cloud, brilliance of the moonlight, or strength or direction of the wind. Observation was suspended shortly after 15^h."

We got in communication with the broadcasting station in Perth and they announced to their subscribers that a storm was on and asked for reports on reception and auroral appearances during the next five days. The electrical engineer of the Western Australia Government Railways reports that there was a total interruption on the main eastern lines beginning at 23^h30^m (G. M. T.) January 26 while readings of the current at one-minute intervals from 1^h20^m to 1^h25^m on January 27 were +13, −4, +6, −6, and +8 milliamperes; the current fluctuated very rapidly. The Eastern Telegraph Company at Perth reported that there was a complete interruption for about an hour on the east-west line to Adelaide but that the north-south line to Cocos Island was not affected. Only one report on radio reception was received it being stated that there was a certain amount of fading. Mr. Cairns at the Observatory did not observe any fading except for a short time on January 27 in the evening.

Earthquake record January 25, 1926.—There was an unusually protracted disturbance due to an earthquake on the magnetogram for January 25, 1926. Unfortunately, the declination and horizontal-intensity traces from which the phases of such a disturbance can ordinarily be scaled, are close together and each has, to some extent, obscured the other.

However, for the horizontal component, the declination variometer gives two phases or periods of disturbance, one from 0^h46^m to 0^h50^m which is much less sustained than the second which lasts from 0^h58^m to 1^h16^m. The trace from the horizontal-intensity variometer indicates the second disturbance much more clearly than the first, and extends, apparently, from 0^h50^m to 1^h31^m.

On the vertical-intensity trace the perturbations are apparent from 0^h47^m to 1^h43^m but the most violent oscillations are confined to the period from 1^h00^m to 1^h20^m. At 1^h10^m either an unusually large amplitude is registered, or else a resonance effect manifests itself. At this point the amplitude is almost double that of the other largest oscillations.

The disturbance coincides approximately with an earth tremor reported in the daily press but in the absence of the seismological bulletin it is difficult to decide on the various phases.

All times given are Greenwich mean time.

H. F. Johnston, *Observer-in-Charge.*

Department of Terrestrial Magnetism,
Carnegie Institution of Washington, Watheroo, Western Australia.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE CHELTENHAM MAGNETIC OBSERVATORY, JANUARY TO MARCH, 1926.[1]

(Latitude, 38° 44′.0 N.; longitude, 76° 50′.5, or $5^h\ 07^m.4$ W. of Greenwich.)

Greenwich Mean Time								Range		
Beginning				Ending				Decl'n	Hor. Int.	Vert. Int.
1926		*h*	*m*	1926		*h*	*m*	′	γ	γ
Jan.	26	16	18	Jan.	27	5	..	86.0	548	356
Feb.	23	16	26	Feb.	25	4	..	61.8	424	301
Mar.	5	10	03	Mar.	6	8	..	33.0	286	118

Geo. Hartnell, *Observer-in-Charge.*

MAGNETIC STORM OF JANUARY 26, 1926, AS RECORDED AT THE SITKA MAGNETIC OBSERVATORY.

(*Greenwich mean time*)

	Maximum			Minimum			Normal Value
	h	*m*	° ′	*h*	*m*	° ′	° ′
D	18	37	32 34.6 E.	16	44	29 13.3 E.	30 27.0 E.
H	25	45	16020γ+	18	40	14630γ−	15500γ
Z	22	38	55725γ+	16	54	55010γ−	55460γ

[1]Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

The foregoing information regarding the magnetic storm of January 26, 1926, as recorded at the Sitka Observatory, has been prepared from the monthly tabulation of hourly values. The magnetograms have not yet been sent in, so that the exact time of beginning and more details regarding phases can not be given at present date (March 18). E. Lester Jones.

MAGNETIC STORM OF JANUARY 26, 1926, at Apia.

We had a rather spectacular magnetic storm on January 26 to 27, 1926. A part of the horizontal-intensity record looks almost like a seismogram of a local earthquake. At one place there is a change of 100 gammas within 6 minutes. I had the same experience as in 1921. I was making observations of declination and became aware of the disturbance when I found my magnets would not come to rest. I did not expect the observations to be of any value, but to my surprise the sets are quite consistent with one another as regards the base-line values and with other observations during the month.

Apia Observatory, C. J. Westland,
Western Samoa, Feb. 11, 1926. *Assistant Director.*

PRELIMINARY REPORT ON ANNUAL VALUES OF MAGNETIC ELEMENTS AT THE SWIDER MAGNETIC OBSERVATORY IN POLAND, 1921-1924.

(*Latitude*, 52°07′ N; *Longitude*, 21°15′ E.)

The Polish Magnetic Observatory at Swider, built in 1914, is situated on the territory which was the scene of most fierce battles during the world war, as well as during the war with bolsheviks, and it is, accordingly, working regularly only since the beginning of 1921. Since that time quarterly bulletins of our magnetic character numbers are included in the "Lists" published by the De Bilt Observatory. Unfortunately, difficult financial conditions and, in consequence, inadequate personnel have hindered us from preparing immediately and publishing detailed reports of our observations. We have only been able to complete the reductions covering the years 1921 to 1924, inclusive, and although there are still some outstanding computations to be made before final results can be given, I consider it desirable to publish the preliminary values which follow:

	D (West)	I	H	Z
	° ′	° ′	γ	γ
1921.5	3 30.3	66 35	18708	43196
1922.5	3 20.7	66 37	18686	43206
1923.5	3 09.5	66 39	18672	43251
1924.5	2 58.0	66 42	18645	43294

Warszawa, Górnóslaska 26 m. 3. St. Kalinowski.
January 31, 1926.

LATEST ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT OBSERVATORIES.[1]

COMPILED BY J. A. FLEMING.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Matochkin Shar	73 16 N	56 14 E	1923	20 35 E	80 03 N	.0952	.5427
Sodankylä.....	67 22 N	26 39 E	1917	0 42.0 E	75 27.7 N	.12765	.49219
			1918[2]	0 48.0 E	75 30.3 N	.12715	.49184
			1921	1 13.3 E	75 37.6 N	.12605	.49188
			1922	1 22.6 E	75 40.5 N	.12561	.49187
			1923[2]	1 32.0 E	75 42.6 N	.12520	.49153
Pavlovsk......	59 41 N	30 29 E	1920	2 42.7 E	71 11.2 N	.15978	.46897
			1921	2 50.6 E	71 14.2 N	.15936	.46910
			1922	2 58.9 E	71 17.3 N	.15895	.46927
			1923	3 07.1 E	71 20.0 N	.15858	.46943
			1924	3 16.1 E	71 23.3 N	.15818	.46970
Sitka..........	57 03 N	135 20 W	1923[2]	30 28.9 E	74 22.1 N	.15549	.55573
			1924[2]	30 28.7 E	74 22.0 N	.15536	.55519
			1925[2]	30 27.2 E	74 22.2 N	.15524	.55488
Katharinenburg	56 50 N	60 38 E	1923	11 00.3 E	71 54.2 N	.16638	.50915
			1924	11 00.8 E	71 58.4 N	.16578	.50942
Rude Skov.....	55 51 N	12 27 E	1921	7 45.2 W	69 01.2 N	.17105	.44607
			1922[2]	7 33.8 W	69 02.6 N	.17087	.44615
Kasan[3]........ (new site)	55 50 N	48 51 E	1915	8 24.3 E	69 28.8 N	.17829	.47635
			1916	8 27.9 E	69 32.8 N	.17760	.47619
			1917	8 31.3 E	69 37.1 N	.17696	.47630
			1918[4]	8 32.9 E	69 43.9 N	.17640	.47768
			1919[5]	8 37.8 E	69 45.6 N	.17570	.47651
			1920[6]	8 39.6 E	69 48.1 N	.17530	.47650
			1921[7]	8 43.1 E	69 56.5 N	.17458	.47813
			1922[8]	8 44.5 E	70 00.2 N	.17401	.47817
			1923	8 50.4 E	70 02.4 N	.17367	.47819
			1924	8 53.5 E	70 07.6 N	.17310	.47888

[1] See tables for previous years in *Terr. Mag.*, vol. 4, p. 135; vol. 5, p. 128; vol. 8, p. 7; vol. 12, p. 175; vol. 16, p. 209; vol. 20, p. 131; vol. 22, p. 169; vol. 23, p. 191; vol. 25, p. 179; vol. 26, p. 147; vol. 27, p. 157; and vol. 29, p. 149; some annual values already published in the tables for previous years are repeated to show secular-change rates.

[2] Preliminary values

[3] Absolute observations only; values of Z as computed from H and I.

[4] No observations in August and September.

[5] No observations in January, February, and November.

[6] No observations in February and March.

[7] No observations in January, February, March, and April.

[8] No observations in February.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Eskdalemuir...	55 19 N	3 12 W	1920	16 49.7W	69 39.5 N	.16706	.45062
			1921	16 37.3W	69 40.3 N	.16695	.45062
			1922	16 25.8W	69 40.0 N	.16680	.45012
Meanook......	54 37 N	113 20W	1923	27 23.3 E	77 53.2 N	.12881[9]	.60025[9]
			1924	27 17.7 E	77 53.7 N	.12866[10]	.59984[10]
Stonyhurst.....	53 51 N	2 28W	1923	15 17.7W	68 41.6 N[3]	.17308	.44377
			1924	15 05.3W	68 41.7 N[3]	.17276	.44281
Irkutsk........ (new site)	52 28 N	104 02 E	1919	1 06.9 E	71 05.8 N	.19307	.56382
			1920	1 02.3 E	71 06.6 N	.19277	.56337
Potsdam.......	52 23 N	13 04 E	1923[2]	6 56.9W	66 36.5 N	.18565	.42920
			1924[2]	6 45.0W	66 38.0 N	.18550	.42935
Seddin........	52 17 N	13 01 E	1923[2]	6 58.2W	66 33.5 N	.18603	.42905
			1924[2]	6 46.3W	66 35.0 N	.18588	.42920
Swider.........	52 07 N	21 15 E	1921[2]	3 30.3W	66 35 N	.18708	.43196
			1922[2]	3 20.7W	66 37 N	.18686	.43206
			1923[2]	3 09.5W	66 39 N	.18672	.43251
			1924[2]	2 58.0W	66 42 N	.18645	.43294
De Bilt........	52 06 N	5 11 E	1923	10 50.2W	66 52.6 N	.18378	.43038
			1924	10 38.3W	66 52.7 N	.18372	.43024
Valencia.......	51 56 N	10 15W	1921	19 06.5W	68 03.4 N	.17848	.44299
			1922	18 57.0W	68 03.0 N	.17849	.44289
Bochum.......	51 29 N	7 14 E	1922	9 58.8W	.. ....	......	......
			1923	9 46.8W	.. ....	......	......
Kew..........	51 28 N	0 19W	1921	14 19.9W	66 57.7 N	.18399	.43266
			1922	14 08.8W	66 57.6 N	.18394	.43251
Greenwich.....	51 28 N	0 00	1923	13 35.1W	66 51.8 N	.18429[11]	.43137[11]
			1924	13 22.8W	66 51.7 N[2]	.18426[2]	.43115[2]
Uccle..........	50 48 N	4 21 E	1916	12 28.6W[11]	66 02.4N[11]	.18973[11]	.42694[11]
			1917	12 19.2W	66 02.7 N	.18964	.42684
Val Joyeux.....	48 49 N	2 01 E	1922	12 31.5W	64 39.6 N	.19661	.41517
			1923	12 20.2W	64 39.0 N	.19664	.41504
Munich........	48 09 N	11 37 E	1920	8 03.8W	.. ....	......	......
			1921	7 53.6W	.. ....	......	......
O'Gyalla....... (Pesth)	47 53 N	18 12 E	1917	5 29.9W	.. ....	.20941	......
			1918	5 21.9W	.. ....	.20917	......

[9]No values in February and July.
[10]No values in March.
[11]Corrected value.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Nantes	47 15 N	1 34W	1923	13 23.5W	63 45.8 N	.20212	.41009
Pola	44 52 N	13 51 E	1921[12]	6 38.6W	60 10.3N[13]	.22094	.38537
			1922	6 28.0W	60 12.8N[13]	.22090	.38591
Agincourt	43 47 N	79 16W	1923	7 00.9W	74 44.3 N	.15784	.57849
			1924	7 05.8W	74 44.4 N	.15752	.57733
Tiflis	41 43 N	44 48 E	1912	3 03.1 E	56 46.0 N	.25255	.37545
			1913	3 09.1 E	56 51.1 N	.25257	.37612
Capodimonte	40 52 N	14 15 E	1922	6 25.7W	57 02.6 N	.23705	.36563
Ebro (Tortosa)	40 49 N	0 31 E	1923	11 30.6W	57 32.7 N	.23328	.36680
			1924	11 20.2W	57 30.5 N	.23359	.36678
Coimbra	40 12 N	8 25W	1921	15 13.4W	58 19.2 N	.23110	.37448
			1922	15 04.7W	58 17.0 N	.23096	.37369
			1923	14 54.2W	58 18.9 N	.23110	.37433
Cheltenham	38 44 N	76 50W	1923[2]	6 32.0W	70 58.3 N	.18975	.55018
			1924[2]	6 35.8W	70 59.2 N	.18924	.54918
			1925[2]	6 39.2W	71 00.5 N	.18870	.54826
San Miguel[3]	37 46 N	25 39W	1919	19 30.4W	60 29.5 N	.23105	.40824
			1920	19 24.9W	60 26.0 N	.23123	.40759
San Fernando	36 28 N	6 12W	1923	13 32.6W	53 48.7 N[14]	.25027	......
			1924	13 23.5W	53 46.8 N[14]	.25016	......
Kakioka[15]	36 14 N	140 11 E	1915	5 15.6W	49 31.3 N	.29752	.34863
			1916	5 17.6W	49 31.7 N	.29743	.34859
Tsingtau	36 04 N	120 19 E	1919	4 09.9W	52 07.4 N	.30812	.39613
			1920	4 12.9W	52 07.0 N	.30817	.39610
Tucson	32 15 N	110 50W	1923[2]	13 47.3 E	59 28.8 N	.26794	.45450
			1924[2]	13 46.4 E	59 29.4 N	.26745	.45386
			1925[2]	13 45.3 E	59 30.6 N	.26687	.45323
Lukiapang	31 19 N	121 02 E	1919	3 20.0W	45 31.0 N	.33187	.33790
			1920	3 21.4W	45 30.7 N	.33175	.33773
Dehra Dun	30 19 N	78 03 E	1921	1 47.1 E	45 04.2 N	.32945	.33025
			1922	1 43.2 E	45 08.6 N	.32927	.33091
			1923	1 38.6 E	45 12.6 N	.32926	.33168
Helwan	29 52 N	31 20 E	1918	1 38.4W	41 06.1 N	.29948	.26126
			1919	1 30.6W	41 09.6 N	.29941	.26175

[12] For 4 months September to December only.

[13] Magnetograph values for hours 2, 6, 10, 14, 18, and 22; other values for all hours.

[14] These values result from absolute observations with dip circle and two needles, the individual results showing great and irregular differences.

[15] The observatory records from January 1917 to August 1923 were lost in the fire at Tokyo following the earthquake of September 1, 1923.

Observatory	Latitude	Longitude	Year	Declination (*D*)	Inclination (*I*)	Intensity Hor. (*H*)	Intensity Ver. (*Z*)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Hongkong (new hut)	22 18 N	114 10 E	1923	0 23.2W	30 44.7 N	.37295[11]	.22183[11]
			1924	0 23.8W	30 42.8 N	.37294	.22155
Honolulu	21 19 N	158 04W	1923[2]	9 58.9 E	39 23.9 N	.28772	.23635
			1924[2]	10 00.2 E	39 24.5 N	.28745	.23618
			1925[2]	10 01.8 E	39 25.9 N	.28708	.23607
Teoloyucan	19 45 N	99 11W	1921	9 10.0E[16]	.. ....	......	......
			1922	9 09.9 E	.. ....	......	......
Toungoo	18 56 N	96 27 E	1921	0 26.8W	23 07.0 N	.39132	.16704
			1922	0 29.7W	23 07.2 N	.39156	.16717
Alibag	18 38 N	72 52 E	1921	0 15.9 E	24 59.5 N	.36956	.17226
			1922	0 12.6 E	25 05.0 N	.36967	.17303
Vieques[17]	18 09 N	65 27W	1923[2]	4 08.3W	51 38.1 N	.27629	.34902
			1924[2]	4 14.9W	51 41.9 N	.27570	.34908
Antipolo	14 36 N	121 10 E	1920	0 35.9 E	16 11.7 N	.38100	.11065
			1921	0 34.2 E	16 07.8 N	.38116	.11028
Kodaikanal	10 14 N	77 28 E	1921	1 54.2W	4 38.5 N	.37832	.03071
			1922	1 58.7W	4 40.1 N	.37878	.03093
Batavia—Buitenzorg	6 11 S	106 49 E	1920[18]	0 47.0 E	31 53.7 S	.36796	.22899
			1923[3]	0 52.2 E	32 00.9 S	.36805	.23012
			1924[3]	0 52.9 E	32 04.3 S	.36821	.23073
Huancayo	12 03 S	75 20W	1923[19]	8 04.6 E	0 45.6 N	.29784[11]	.00395
			1924[19]	8 01.7 E	0 54.6 N	.29762	.00473
Apia	13 48 S	171 46W	1923[20]	10 16.2 E	30 06.6 S	.35250	.20441
			1924[2]	10 19.2 E	30 07.5 S	.35249	.20453
Tananarivo	18 55 S	47 32 E	1913	8 31.4W	53 39.0 S	.22492	.30563
			1914	8 25.2W	53 37.9 S	.22484	.30532
Mauritius	20 06 S	57 33 E	1921	10 30.7W	52 37.1 S	.23061	.30185
			1922	10 39.9W	52 36.2 S	.23019	.30112
			1923	10 49.2W	52 33.7 S	.22982	.30017
			1924	10 59.7W	52 32.2 S	.22943	.29940
Vassouras	22 24 S	43 39W	1922	11 34.1W	15 44.2 S	.24431	.06884
			1923	11 42.8W	15 53.7 S	.24407	.06950

[16]No observations in May and September.

[17]Records at the Vieques Observatory were discontinued November 1, 1924 (the values given for 1924 apply for the first 10 months only) and a new observatory to replace it was built about eight miles south of San Juan, Porto Rico; recording began at the new observatory on January 1, 1926.

[18]Final magnetograph values.

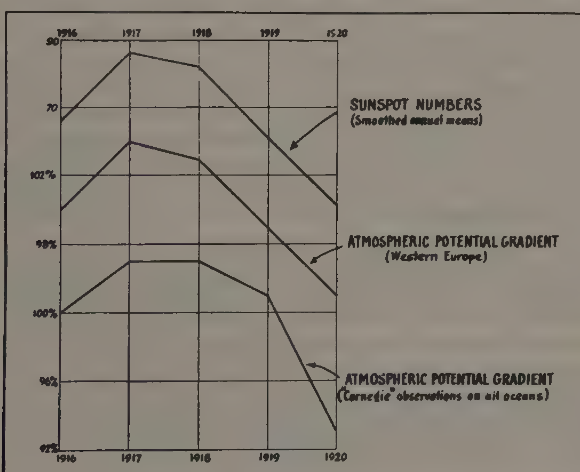
[19]Preliminary means of absolute values determined weekly.

[20]Corrected magnetograph values.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Watheroo......	30 19 S	115 53 E	1923[21]	4 19.5W	64 03.0 S	.24777	.50914
			1924[21]	4 18.3W	64 05.2 S	.24750	.50941
			1925[22]	4 17.7W	64 07.9 S	.24719	.50977
Pilar..........	31 40 S	63 53W	1920	7 48.6 E	25 41.2 S	.25297	.12168
			1921	7 40.2 E	25 39.2 S	.25241	.12122
			1922	7 31.9 E	25 39.1 S	.25178	.12091
Toolangi.......	37 32 S	145 28 E	1920[3]	8 00.8 E	67 55.1 S	.22874	.56384
Christchurch...	43 32 S	172 37 E	1923	17 11.7 E	68 12.0 S	.22209	.55526
			1924	17 16.4 E	68 17.7 S	.22188	.55508
Orcadas.......	60 43 S	44 47W	1911	4 48.8E[23]	54 26.5S[24]	.25384[23]	......
			1912	4 46.5 E	54 26.0S[3]	.25343	.35442

[21]Final means from magnetograms.
[22]Preliminary means from magnetograms.
[23]Mean for 9 months, April to December.
[24]Mean of absolute values during March to December.

ACTIVITY OF THE SUN AND OF ATMOSPHERIC ELECTRICITY ON LAND AND AT SEA, 1916-1920.



For explanations, the interested reader may be referred to "Researches Dept. Terr. Mag." Vol. 5, p. 381 (Pub. No. 175, Vol. V, Carnegie Institution of Washington, 1926).

LOUIS A. BAUER.

NOTES

1. *Transactions, Madrid Meeting of Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union, 1924.*—The "Transactions," contained in an octavo volume of VIII, 180 pages, and edited by Louis A. Bauer as secretary of the section and director of its central bureau, appeared in November 1925 as "Bulletin No. 5" from the Johns Hopkins Press of Baltimore, Maryland. The typographical work was done by the Caxton Press of Cincinnati, Ohio. The volume contains the following: Part I.—Proceedings and Minutes, Madrid Meeting; Part II.—Reports of Special Committees, Atmospheric Electricity, Earth-Current Observations, Polar Lights, Magnetic Characterization of Days, Magnetic Surveys and International Comparisons of Instruments, Actions on Reports of Special Committees; Part III.—Reports of National Committees, Status of Magnetic Surveys, Magnetic Instruments, Constants, and Comparisons, Reports on Observatory Work, 1924, Communications on Terrestrial Electricity, On Questions of the Agenda, General Information, Adhering Countries, Officers of the Union and of its Sections, National Sections for Terrestrial Magnetism and Electricity, 1925, National Committees for Geodesy and Geophysics, 1925, and Addresses.

2. *International Geodetic and Geophysical Union.*—According to Bulletin No. 5, referred to in the preceding note, the following countries at the end of August 1925 had joined the Union: Australia, Belgium, Brazil, Canada, Chile, Czechoslovakia, Denmark, France, Greece, Holland (only Section of Geodesy), Italy, Japan, Mexico, Morocco, Norway, Peru, Poland, Portugal, Siam, South Africa, Spain, Sweden, Switzerland, Tunis, United Kingdom (Great Britain and Ireland), United States, and Uruguay. Since then information has been received that Egypt, Finland and Yugoslavia have joined Union, also that New Zealand is making preparations to join.

3. *American Geophysical Union.*—This Union which functions as the United States Section of the International Geodetic and Geophysical Union will have its annual meeting at Washington on April 29 and 30, 1926.

4. *Australian National Committee of Geodesy and Geophysics.*—This Committee consists at present of the following: Dr. J. M. Baldwin, Prof. L. A. Cotton, Prof. Sir Edgeworth David, Mr. G. F. Dodwell, Dr. W. G. Duffield, Prof. Kerr Grant, Dr. E. Kidson, Sir George Knibbs, Dr. E. F. J. Love (*Secretary*), Prof. Sir Thomas Lyle, Rev. E. F. Pigot, and Prof. A. D. Ross.

5. *Deutsche Geophysikalische Gesellschaft, December 1925.*—The fourth meeting of the German Geophysical Society was held at Göttingen on December 7-9, 1925. Among the papers on terrestrial magnetism and electricity were the following:

Angenheister (Göttingen), Schall beobachtungen, luftelektrische, magnetische Demonstrationen; *Linke* (Frankfurt), Atmosphärische Strahlungsprocesse; *Meisser* (Jena), Zur Weiterentwicklung der Drehwage. Absolute Inklinations-messungen im Gelände; and *Schmidt* (Potsdam), Über den magnetischen Mittelpunkt der Erde.

6. *Zi-ka-wei Observatory.*—A grant of 4000 francs has been made by the French Academy of Sciences, to Father Lejay of the Zi-ka-wei Observatory, in order that he may complete his investigations of atmospheric electricity.

7. *Porto Rico Magnetic Observatory.*—*Wallace M. Hill*, magnetic observer, relieved Leutenant *R. J. Auld* of the charge of the new magnetic observatory near San Juan, Porto Rico, early in March. Prior to the transfer, Mr. Hill made absolute observations at the site of the old absolute observatory on Vieques Island, for the purpose of connecting the results of the two observatories.

8. *Personalia.*—Prof. *G. N. Armstrong* of Ohio Wesleyan University, connected with the Department of Terrestrial Magnetism during the summer of 1914, died on January 7, 1926; Prof. *Luigi Palazzo* made a series of magnetic observations in Jubaland and during the solar eclipse of January 14, 1926; M. *Georges Perrier* has been elected to fill the place made vacant by the death of *L. Gentil*, in the Section of Geography and Navigation of the French Academy of Sciences, and M. *Jean Charcot* to replace *M. E. Tisserand*; the Hughes Medal of the Royal Society was presented on November 30, 1925 to Mr. *F. E. Smith* for various important investigations, one of which dealt with the measurement of the intensity of the Earth's magnetic field and led to the construction of the Schuster-Smith electric magnetometer; Dr. *Harald U Sverdrup*, in charge of the scientific work of the Amundsen Arctic Expedition, aboard the *Maud*, 1918-1925, has been appointed Research Associate of the Carnegie Institution of Washington for the period March–August 1926, in order to enable him, in co-operation with the Department of Terrestrial Magnetism, to complete the reduction and publication of his observations, chiefly in terrestrial magnetism and electricity; Sir *Gilbert Walker*, professor of meteorology at the Imperial College of Science and Technology at South Kensington was elected President of the Royal Meteorologicial Society at its annual meeting on January 20, 1926.

A. Walter, formerly in charge of the Mauritius Observatory, has been appointed to the post of director of the Statistical Bureau, Mombassa, Kenya Colony, East Africa, beginning with June 1926. Rev. *José Algué*, owing to ill health, resigned the directorship of the Manila Observatory, and the Rev. *Miguel Selga* is at present the Acting Director.

The David Livingstone Centenary Medal for 1926 of the American Geographical Society was awarded to Professor *Erich von Drygalski* for his work in the Antarctic regions. The Cullum Geographical Medal for 1925 of the same Society was awarded to Señor *Pedro C. Sanchez*, director of the Central Mexican Bureau of Geography and Climatology, for his contributions to Mexican cartography.

Robert T. Booth will be succeeded on April 1 by *Richard H. Goddard* as observer-in-charge of the Huancayo Magnetic Observatory (Peru) of the Carnegie Institution of Washington.

9. *Stoermer's Aus den Tiefen des Weltenraums.*[1]—This very attractive book by Prof. Stoermer, of which the German translation was undertaken by Dr. *I. Weber*, is a most timely one. Within convenient compass is brought together a mass of information pertaining to the latest discoveries in astronomy, gravitation, polar lights, atomic physics, Röntgen rays, radium, age of the Earth, penetrating radiation (cosmic rays), and vibrations of the ether. The reader will find the booklet both instructive and stimulating. At the close are given for the benefit of anyone who desires fuller information, references to books, articles, and journals. An English translation is shortly to appear.

10. *Dingle's Modern Astrophysics.*[2]—Prof. *Herbert Dingle*, of the Imperial College of Science and Technology, has assembled most satisfactorily, in this book of 420 octavo pages, intended primarily for the general public, the latest achievements and results of investigations in the borderland of physics and astronomy. The section-headings are as follows: I. Spectroscopy; II. Characteristics of the Stars; III. Varieties of Cosmic Bodies; and IV. The Universe (As it is; As it was; and As it will be). Many attractive plates are distributed throughout the volume.

11. *Wolf-Wolfer Sunspot Numbers.*—Prof. *A. Wolfer*, on account of age limit, retires on April 1, 1926 from the directorship of the "Eidgenössiche Sternwarte" at Zürich, Switzerland. The so-called "relative sunspot-numbers," which he continued after the death of Prof. *Wolf* on December 6, 1893, owing to the promptness of their appearance, have been of inestimable help to those studying the relationships between solar and geophysical phenomena. However, we are assured that the continuance of these measures of solar activity will be maintained by Wolfer's successor, Prof. *William Brunner*.

12. *Tashkent Magnetic Observatory.*—According to information received from the director, Dr. *Richard Zimmermann*, the buildings for the magnetic and electric observations at this observatory in Turkestan were completed some months ago. Unfortunately, however, electric car-lines approach the observatory sufficiently close as to cause appreciable disturbances on the magnetograph records. Dr. Zimmermann also proposes to make a *magnetic survey of Turkestan.*

13. *Magnetic Observatories in India.*—The magnetic operations, except at the Dehra Dun observatory, were suspended in October 1923, when the Toungoo observatory was dismantled, the observatory buildings being handed over to the Director, Burma Circle. The declination, horizontal intensity and vertical intensity magnetographs were in operation throughout the fiscal year at the (October 1923-September 1924) Dehra Dun observatory and daily absolute observations were taken by the observer in charge. The results of the observations at the Dehra Dun, Toungoo, Barrackpore, Kodaikanal and Alibag observatories, and at the repeat and field stations, reduced to epochs 1909.0 and 1920.0 are now under publication.

[1]Stoermer, Carl. Aus den Tiefen des Weltenraums bis ins Innere der Atome Deutsche Ausgabe von *I. Weber*. F. A. Brockhaus, Leipzig, 1925. 196pp. and 16 illustrations.

[2]Published by The Macmillan Company of New York, 1924.

GOCKEL, ALBERT; *Das Gewitter.* Dritte, vielfach geänderte Au age. Berlin, Ferd. Dümmlers Verlagsbuchhandlung, 1925 (viii + 316 mit 3 Taf. und 36 Abb.).

Twenty years have passed since the second edition of Dr. Gockel's book on thunder-storms appeared In this period the researches in atmospheric electricity particularly the studies of the electrical charges on precipitation and dust, have thrown new light on the electrical phenomena of the thunder-storm, making a revision and extension desirable. The new edition of Dr. Gockel's book is presented in an attractive form, but it is to be regretted, that several typographic errors have been overlooked in the proof-reading.

This edition contains, as does the second edition, a large number of fascinating and vivid descriptions of thunder-storms and of the various forms of electrical discharges in the atmosphere, such as ordinary lightning, sheet-lightning, and the mysterious beaded and ball lightnings. Descriptions are added of the volcanic thunder-storms, in which ashes and solid particles appear to take the place of rain-drops and snow-crystals as carriers and distributors of the electrical charges. The meteorological part of the book is in the main unchanged, but some of the recent developments in dynamical meteorology bearing on the dynamics of the thunder-storm have been taken into account.

The discussion of the electrical field of the Earth has not been much extended, probably because the latest results of the general researches are of minor importance to the special problems met with, when dealing with the thunder-storms, but a new chapter, "Entstehung der Gewitterelektrizität" gives a highly valuable summary of recent studies of the electrification of dust, ice-crystals, and raindrops by friction or disruption. Laboratory experiments show that particles of different sizes generally become charged with electricity of opposite sign, depending upon the size of the particle. Whether the larger become positive and the smaller negative, or *vice versa*, depends on the substance of the particles. If raindrops are disrupted the larger parts will be charged positively and the smaller negatively, but if ice-crystals are broken up the reversed rule is followed. In nature, disruption may be brought about by collisions, or by the turbulent motion of the air. The larger part will fall more rapidly than the smaller, which may be kept floating or even carried upwards by vertical air-currents. In this way the electrical charges may be separated and computation shows the process may be sufficiently intensive to produce the accumulation of electrical charges observed in thunder-storm clouds. There remain, however, a number of features which cannot be accounted for by the results of the experiments here referred to, as for instance, the fact that large rain-drops frequently are charged negatively. This and many other features can be explained if the influence of the Earth's electric field is considered. The Earth is generally negative compared to the atmosphere for which reason a falling rain-drop by distribution becomes charged positively on the lower part and negatively on the upper. This large rain-drop may overtake a smaller one. The latter may for a moment touch the lower part of the large drop and slide off, carrying away part of the positive charge and leaving the large drop with a negative charge. It has been disputed that rain-drops of different sizes can collide without uniting as here supposed, but experiments carried out in Dr. Gockel's laboratory indicate that such collisions are possible. When the atmospheric-electric field is strong enough, it seems possible, that the charges on the opposite sides of the rain-drops may become so large that the drop is torn apart, and the charges may become distributed as by mechanical disruption of the drop.

The effects of the electrification by friction and disruption combined with the influence of the electric field of the Earth seem sufficient to explain all outstanding electrical phenomena which are observed in connection with precipitation, but those electrical discharges taking place without being accompanied by precipitation of any kind present difficulties. Dr. Gockel concludes this chapter, saying that now it appears possible to form a satisfactory theory as to the origin of the thunder-storm electricity, which is based upon well-established results, even though several details remain to be explained. It is no longer necessary to advance theories which lack experimental foundation.

In the chapter dealing with the periodicities of thunder-storms, Dr. Gockel draws attention to the recent investigations of Dr. L. A. Bauer, which have disclosed a relationship between the atmospheric-electric phenomena and the activity of the sun, emphasizing that these results give an increased interest to studies of the relation between thunder-storms and solar activity. The frequency of thunder-storms shows a variation in 11 years, corresponding to the sunspot-period, but the character of the variation is different in different parts of the world, perhaps indicating that the fluctuations in frequency are resulting not from changes in the electric field of the Earth, but from changes in the atmospheric circulation.

The new edition of "Das Gewitter" must be welcomed by every one who is interested in the stupendous phenomena of thunder-storms and contains such a variety of information, that it will be of equal interest to the professional and lay reader.

H. U. Sverdrup.

Atlas Magnetique. *Publié sous la direction de Ch. Maurain, avec la collaboration de L. Eblé, par Mme de Madinhac et Mlle Homery.* Paris, Les Presses Universitaires de France, 1925 (viii+16 avec 23 cartes). 31 cm.

This atlas, issued in the attractive style and format of the Annales de l' Institut de Physique du Globe fulfils a two-fold desire, viz., (1) to collect and reduce to a common epoch the various magnetic results obtained at different times in the French possessions and to construct magnetic charts for those regions where data are sufficiently abundant, and (2) to satisfy the demands of aviation services for information regarding the magnetic declination at different points on European routes.

The charts are preceded by a brief introduction and a notice by Professor Maurain on the variations and distribution of the Earth's magnetic field, as also by some remarks by Mme de Madinhac on the magnetic declination in Western Europe on January 1, 1921.

The charts for France, based on the survey laid out by Moureaux and continued by others, give the declination, inclination, and horizontal intensity, reduced to the epoch January 1, 1921 (1921.0). The charts for the other European countries, likewise reduced to January 1, 1921, show the declination only, and have been constructed on the basis of the available magnetic data for those countries.

To complete the atlas, charts of lines of equal magnetic declination, inclination, and horizontal intensity for the entire globe have been added, which are a simplified reproduction of the large British Admiralty charts for the epoch January 1, 1922; however, in the preparation of the various annual secular variation maps (chart No. 4), values derived from comparisons made during the survey work in France, which differ slightly from those of the British charts, have been used.

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STUDIES CONCERNING THE RELATION BETWEEN THE ACTIVITY OF THE SUN AND OF THE EARTH'S MAGNETISM.—NO. II.

By Louis A. Bauer and C. R. Duvall.

Abstract.—This article is a continuation of the previous one by the authors on the same subject. With the aid of additional data, it is once more found that the quantities a and b in the formula $Q=a+b\,S$ vary with sunspot activity, and apparently also with time; Q is the measure of magnetic activity, and S that of solar activity.

The parameter a varies directly, and b inversely with sunspot activity. The measure of magnetic activity, Q, is evidently subject to the same periodicities as found by various authors from analyses of the sunspot numbers. Thus an analysis of concomitant magnetic and sunspot data for the period 1841 to 1910 made by G. N. Armstrong and C. R. Duvall at the Department of Terrestrial Magnetism, in the summer of 1914, indicated the existence of periods of about 11.4 years, 22 years, and a third in the neighborhood of 70 years.*

1. Our article published in the December 1925 number of "Terrestrial Magnetism" on the above subject will be designated for brevity of reference as "MI." Since its preparation two important papers have come to hand, one by J. Bartels[1] and the other by J. M. Stagg.[2] These papers contain data which, combined with ours, will throw additional light on the variability of a and b, in the formula (1), $Q=a+b\,S$, where Q and S are, respectively, measures of magnetic and of solar activity. It may be recalled that a and b were found not to be "constants," even if the magnetic and solar measures applied to whole years. The parameter a appeared to vary directly, and the parameter b inversely with solar activity (see MI, §9). We also had evidence of an intercycle variation of a and b, implying the addition of a supplementary term in formula (1), as was stated in §20 of MI.

2. Mr. Stagg's paper supplies the missing values of the absolute declination ranges for *all* days at the Kew Observatory for the period 1901-1910. Chree had discussed the values for the period 1858-1900 (see MI, footnote 1, reference CIII), and we had utilized his data in Table 1 (MI, p. 194). We further have the absolute declination ranges at Kew for the period 1911-1915, as taken from

*Annual Report of the Director of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, 1914, pp. 319, 320.

[1] Bartels, J. Erdmagnetische Aktivität 1836-1923. Berlin, *Veröff. Met. Inst.*, Nr. 332 (*Arch d. Magnetismus*, Heft 5), 1925, pp. 45-49.

[2] Stagg, J. M. The absolute daily range of magnetic declination at Kew Observatory, Richmond, 1901 to 1910. London, Met. Office, *Geophys. Mem.*, No. 29, 1926, pp. 241-265.

the various issues of the "Geophysical Journal of the British Meteorological and Magnetic Year Book." After 1915 the publication of these values was discontinued because of the disturbing effect of the electric car lines on the Kew magnetograms. However, we have the absolute declination ranges for complete years at the Cheltenham Magnetic Observatory, Maryland, for the period, 1902-1925 (also for the portion of year April-Dec. 1901). We are indebted to the Director (Col. E. Lester Jones) of the United States Coast and Geodetic Survey for the data 1901-1904, which were not given in the usual form in the regular publications of the Cheltenham Observatory for the first years of its existence, and also for the data 1923-1924 in advance of publication.

3. With the aid of Bauer's tentative, equalizing formula (9), as given on p. 194 of MI, and the concomitant data for full 14 years at Kew and Cheltenham, 1902-1915, it has been possible to prepare Table 1 giving the yearly magnetic measures, dependent on *daily* ranges, for the 6 solar cycles 1856-1922, which constitutes the most homogeneous series, in the absence of similar published data for other observatories, at present available for comparisons with measures of solar activity. The magnetic data have finally been referred to Cheltenham for the reason that Kew Observatory has been discontinued since January 1925 and the current data at Cheltenham are always promptly supplied us by the Director of the Coast and Geodetic Survey. Besides, the *magnetic* latitude of Cheltenham is 55° (geographic latitude is 38°.7 N); hence, this observatory is in a location intermediate between the regions of equatorial and polar magnetic disturbances, and thus is fairly representative of average conditions for the whole Earth. It was already explained in footnote 3 of MI that Kew data for the years 1856 and 1857 and for the missing year 1874 "were obtained by comparison of the Kew and Greenwich results for close-by years"; these data are now referred to Cheltenham as explained for the other Kew values.

4. The quantities in Table 1 are those of W_D (formula 9, MI), all expressed in the unit of work, ϵ (MI, §5). The yearly ratios W_D (Cheltenham): W_D (Kew) for the period of simultaneous observations, 1902-1915, varied from 1.10 (1903, 1914, and 1915) to 1.32 in 1906 and 1.31 in 1910; the mean value for the 14 years was 1.20 and this is the reduction factor which has been used to refer the Kew data to the Cheltenham station. It is quite possible that this factor may be somewhat variable with time, or with solar activity, since pronounced magnetic disturbances might not always, because of the particular magnetographs used, be fully registered at both observatories. As regards the latter question, we arranged the corresponding values of W_D at Kew and Cheltenham into two groups, each consisting of 7 years, Group I containing the years of high sunspot numbers and Group II, the years of low sunspot numbers; the mean results are as follows:

Group I				Group II		
Mean Sunspot Number	W_D Kew	W_D Chel.		Mean Sunspot Number	W_D Kew	W_D Chel.
	ε	ε			ε	ε
51.6	11.72	14.26		9.8	10.02	11.85
	C:K = 1.22				C:K = 1.18	

Thus while there is some indication that the reduction factor is dependent upon sunspottedness, the variability is so slight that we do not feel justified, at present, in using other than a constant factor (1.20).

5. It was shown in Table 3, p. 197 of MI that, for *yearly* comparisons, the Wolf-Wolfer relative sunspot numbers give values of the correlation coefficient only slightly inferior to those derived from the Greenwich sunspot areas, or from our variability measures[3] of the sunspot numbers and areas. As the relative sunspot numbers have been carefully worked out by Wolf and Wolfer for a long period of years,[4] we do not think that there will be any material gain from a *physical* standpoint, to attempt the task of working out a similar series of solar measures, dependent on other data, for a correspondingly long period; hence in Table 1 we have used as yearly measure of solar activity the Wolf-Wolfer numbers, S_n.

TABLE 1.—*Solar and magnetic measures of activity, 1856-1924.*

(S_n = Wolf-Wolfer relative sunspot numbers; W_D values are based on absolute declination ranges on all days at Kew and Cheltenham referred to a common basis.)

Year	S_n	W_D	Year	S_n	W_D	Year	S_n	W_D	Year	S_n	W_D	Year	S_n	W_D
		ε			ε			ε			ε			ε
1856	*4.3*	12.6	1870	**139.1**	**22.6**	1884	63.5	16.0	1898	26.7	14.5	1912	3.6	*11.0*
1857	22.8	*12.3*	1871	111.2	21.6	1885	52.2	15.6	1899	12.1	13.4	1913	*1.4*	11.1
1858	54.8	18.0	1872	101.7	22.3	1886	25.4	16.9	1900	9.5	10.9	1914	9.6	11.6
1859	93.8	**20.1**	1873	66.3	19.3	1887	13.1	15.0	1901	*2.7*	*9.7*	1915	47.4	15.1
1860	**95.7**	19.6	1874	44.7	16.1	1888	6.8	14.0	1902	5.0	10.1	1916	57.1	16.2
1861	77.2	18.6	1875	17.1	12.9	1889	*6.3*	*12.7*	1903	24.4	12.9	1917	**103.9**	16.9
1862	59.1	19.1	1876	11.3	12.2	1890	7.1	12.3	1904	42.0	12.7	1918	80.6	17.5
1863	44.0	19.4	1877	12.3	*10.6*	1891	35.6	15.9	1905	**63.5**	14.1	1919	63.6	**18.3**
1864	47.0	18.5	1878	*3.4*	10.7	1892	73.0	**20.5**	1906	53.8	12.9	1920	37.6	15.6
1865	30.5	19.4	1879	6.0	10.7	1893	**84.9**	18.2	1907	62.0	14.5	1921	26.1	13.8
1866	16.3	17.4	1880	32.3	13.5	1894	78.0	19.2	1908	48.5	**15.2**	1922	14.2	13.8
1867	*7.3*	*15.5*	1881	54.3	15.6	1895	64.0	18.2	1909	43.9	14.6	1923	*5.8*	11.1
1868	37.3	17.2	1882	59.7	**18.6**	1896	41.8	17.0	1910	18.6	13.9	1924	16.7	11.3
1869	73.9	19.9	1883	**63.7**	17.1	1897	26.2	14.3	1911	5.7	12.9	1925	44.6	

[3] A *variability* measure of sunspot activity has likewise been employed by Stagg (footnote reference 2, Table XVIII, p. 261). *Cf.* also BAUER, L. A., *Terr. Mag.*, vol. 26 (1921), pp. 46-47.

[4] *Terr. Mag.*, vol. 30 (1925), pp. 83-86.

TABLE 2.—*Values of a_y, b_y, c_y, and r_y according to solar cycles, 1856-1922, deduced from magnetic measures in Table 1.*

($Q_y = a_y + b_y S_n$; $c_y = 100 b_y / a_y$; r_y = correlation coefficient.)

No.	Cycle	S_n	W_D	a_y	$100b_y$	c_y	r_y
			ε	ε ε	ε ε		
1	1856–1866	49.6	17.8	14.6±0.7	6.4±1.3	0.44±0.08	0.73±0.09
2	1867–1877	56.6	17.4	12.5±0.6	8.6±0.8	0.69±0.07	0.92±0.03
3	1878–1888	34.6	14.9	12.1±0.4	7.7±1.4	0.64±0.11	0.78±0.08
4	1889–1900	38.8	15.7	11.8±0.4	10.0±0.7	0.84±0.07	0.94±0.02
5	1901–1912	31.1	12.9	11.1±0.4	5.7±1.0	0.51±0.10	0.76±0.08
6	1913–1922	44.2	14.8	12.2±0.5	6.4±0.9	0.53±0.08	0.87±0.05

6. Table 2 contains the values of the parameters as derived by the method of least squares from the data in Table 1, for the various complete solar cycles indicated in the second column. This Table 2 may be taken as superseding Table 1 of MI, since the tabulated values depend on the most homogeneous series of magnetic data for a period of 67 years at present available. Glancing at the values of a_y in the fifth column, it will be seen that they systematically diminish until the last cycle, which exhibits an increase over the value of the previous cycle. Since the values of a_y all apply to the same sunspot number ($S_n=0$) and as they depend directly on the absolute declination ranges, R_D, *we may conclude, as a first approximation, that during the period considered, 1856-1922, there has been a secular decrease in the declination range*, as Mr. Stagg on pp. 257-258 of reference in footnote 2 also infers from the Kew data 1858-1910.

If instead of obtaining the values of a_y for $S_n=0$, we obtain them for the mean sunspot number ($S_n=42.5$) of the six cycles, thus diminishing the error due to the determination of b_y, the following tentative expression has been established by the method of least squares:

$$a'_y = \overset{\epsilon}{-0.0517}\,(T-1889.6);\; r=0.83\pm0.08 \qquad (1)$$

[Mean value of a'_y ($S_n=42.5$) for period 1856-1922 is 15.6ε.]

The correlation coefficient, 0.83, is sufficiently high as to warrant the conclusion of the existence of an inter-cycle or *t*-term in the original Wolf formula, attention to which was drawn in §20 of MI. It may be recalled that Bauer had previously called attention to this fact, both as regards the activity in atmospheric electricity and terrestrial magnetism.[5] But we should not conclude, especially in view of the increased value of a_y and S_n for Cycle 6 over the corresponding quantities for Cycle 5 that the diurnal range of the magnetic declination, apart from the effect of solar activity, will

[5] BAUER, LOUIS A. Correlations between solar activity and atmospheric electricity, *Terr. Mag.*, vol. 29 (1924), §33, 174-175. *Cf* also *Nature*, vol. 112 (1924), pp. 203-205 and 686.

steadily decrease with time. On the contrary the most that can be said at present is that the diurnal range of the Earth's magnetism, in addition to varying during a solar cycle, is subject to a periodicity corresponding to one of the longer periods, embracing several cycles, already deduced by others from analyses of the sunspot numbers. (*Cf. Abstract*, p. 39.)

7. In view of the discovery by Hale and his collaborators of the reversal of polarity in the magnetic fields of the preceding and succeeding members of bi-polar groups of sunspots from cycle to cycle, as though there were a period consisting of *two* cycles,[6] it is of some interest to note that *the values of c_y and r_y in Table 2 are alternately low and high from cycle to cycle for the 6 cycles, 1856-1922.* This matter will receive fuller investigation later in order to determine whether the results are merely accidental.

8. To investigate once more the question of the variability of a and b with sunspottedness, we have followed the same procedure described in §8 of MI, using this time the longer series of magnetic measures given in Table 1 of the present paper. Two groups of 34 years each were formed, No. I containing the years of high and No. II, the years of low sunspot activity. The results derived by least squares are given in Table 3.

TABLE 3.—*Variability in a_y, b_y, c_y, and r_y with sunspot activity for Table 1.*

Group	T_m	S_{nm}	W_{Dm}	a_y	$100b_y$	c_y	r_y
			ε	ε	ε		
Group I (Years of high S_n).	1887.7	67.9	17.53	12.26	7.76	+0.63	0.68
Group II (Years of low S_n).	1892.3	15.4	13.11	10.90	14.36	+1.32	0.72
I-II...........	−4.6	+52.5	+4.42	+1.36	−6.60	−0.69	−0.04

It will be observed that the mean epoch, T_m, for each group is nearly the same so that the matter of the variability with time of the parameters, as described in §6, will have no effect, practically, on the results in Table 3. Comparing the results for the two groups it appears once more, as found previously in §9 of MI, that *a varies directly and b, inversely with sunspot activity.*

9. That there is a long-period variation in the diurnal range of the Earth's magnetic elements, superposed on the solar-cycle variation (see §6), may be shown with the aid of another series of observations, namely Bombay (Colaba, 1847-1905; Alibag, 1904-1915). Unfortunately the absolute diurnal ranges of the declination and horizontal intensity are not given in any of the observatory publications. However, magnetic measures were computed: (1) from the monthly mean diurnal inequalities (hence, diurnal ranges derived from the momentary mean hourly values for a month); and (2) from what Moos calls "summed ranges," which

[6] For a summary of the results to date pertaining to this matter see article by GEORGE E. HALE and S. B. NICHOLSON, in *Astroph. J.*, vol. 62 (1925), 270-300.

are merely the sums, regardless of sign, of the diurnal inequalities derived from monthly mean hourly values. Dividing the latter quantities by 24 we get what are now more commonly called "average departures." For the period 1902 to 1915 we have such smoothed measures of magnetic activity in D and H for Bombay (Colaba and Alibag) and simultaneous measures of magnetic activity obtained from the absolute diurnal ranges at the Cheltenham Observatory. Using the equalizing formulæ for W_D and W_H, 9 and 10 of MI, we finally obtained values of these measures of magnetic activity at Bombay, referred to Cheltenham, for the period 1856-1912. Following the same procedure as in §6 we have:

$$a'_y \text{ (from } W_D) = \overset{\epsilon}{-0.0262}\ (T-1883.9);\ r=0.92\pm0.04 \qquad (2)$$

[Mean value of a'_y ($S_n=42.1$) for period 1856-1912 is 13.7 ϵ]

$$a'_y \text{ (from } W_H) = \overset{\epsilon}{-0.0292}\ (T-1883.9);\ r=0.96\pm0.02 \qquad (3)$$

[Mean value of a' ($S_n=42.1$) for period 1856-1912 is 12.4 ϵ]

It will be observed that the results in (2) and (3) are identical with those in (1) and that the same conclusion as to a long-period variation in the diurnal range of the Earth's magnetism must again be drawn. The values of r in (2) and (3) are higher than in (1), because of the fact that the effect of magnetic disturbances has been smoothed out somewhat in the Bombay data we have had to utilize.

10. Reference has already been made in §§8 and 12 of MI and in §1 of the present article of the measures of magnetic activity, based on the interdiurnal variability of H, published by Bartels. Examining the values given by him in the publication cited in footnote 1, we have extracted his values of u, reduced by him to the magnetic equator, applying to the Bombay Observatory for the period 1872-1910 and have referred them to the Potsdam values by means of the simultaneous data at these two observatories from 1891 to 1910. While the factor for referring the Bombay results to the Potsdam station varies for individual years, probably because of varying character and magnitude of magnetic disturbances at the two stations, from 0.93 (1902) to 1.08 (1893 and 1908), no dependence, on the average, of the factor on sunspot number is found; we have accordingly adopted a mean value of 1.01. In other words, the values as reduced by Bartels to the magnetic equator by means of formulæ, analogous to Bauer's, for two such stations as Bombay (magnetic latitude 13°N) and Potsdam (magnetic latitude 49°N) are found practically identical, which argues well for Bartels' reduction method.

We next constructed a table of the Bartels' values of u multiplied by 10, so as to express them in gammas and obtain quantities of the same order of magnitude as our measures, for the period 1872 to 1923, dependent alone on Bombay and Potsdam and all referred to the latter station. The following formulæ will exhibit the rela-

tionship between two totally different measures of magnetic activity and the sunspot numbers for the period 1872 to 1923:

$$10\,u = 5^{\gamma}.69 + 0^{\gamma}.0744\,S_n;\ r = 0.87 \quad (4)$$

$$W_D = 11^{\epsilon}.16 + 0^{\epsilon}.0881\,S_n;\ r = 0.87 \quad (5)$$

$$\text{Correlation between } u \text{ and } W_D = 0.94 \quad (6)$$

It is thus seen that the agreement between the two independent sets of magnetic measures is highly satisfactory.

TABLE 4.—*Magnetic measures of the inter-diurnal variability of H and dependent on Bombay and Potsdam, as extracted from Bartels' table, and referred to Potsdam, 1872–1923.*

Year	S_n	$10u$	Year	S_n	$10u$	Year	S_n	$10u$	Year	S_n	$10u$
		γ			γ			γ			γ
1872	102	16.5	1885	52	9.3	1898	27	8.1	1911	6	7.1
1873	66	10.4	1886	25	7.9	1899	12	6.3	1912	4	5.7
1874	45	9.8	1887	13	7.1	1900	10	6.1	1913	*1*	*4.8*
1875	17	6.8	1888	7	7.1	1901	*3*	*4.9*	1914	10	5.9
1876	11	5.9	1889	*6*	6.1	1902	5	5.0	1915	47	8.4
1877	12	6.6	1890	7	*5.4*	1903	24	7.7	1916	57	9.4
1878	*3*	*5.4*	1891	36	8.3	1904	42	7.3	1917	**104**	10.7
1879	6	5.5	1892	73	**13.2**	1905	**64**	8.8	1918	61	11.5
1880	32	8.1	1093	**85**	10.3	1906	54	7.6	1919	64	**11.9**
1881	54	8.9	1894	78	12.6	1907	62	9.2	1920	38	10.9
1882	60	**12.2**	1895	64	9.6	1908	48	9.4	1921	26	10.3
1883	**64**	9.7	1896	42	9.3	1909	44	9.5	1922	14	7.6
1884	64	9.9	1897	26	8.2	1910	19	8.5	1923	*6*	6.2

Mean value of $10u$, 1872–1923 = $8^{\gamma}.44$ (Bombay and Potsdam)

" " " W_D, 1872–1923 = $14^{\epsilon}.42$ (Kew and Cheltenham)

Hence, $W_D : 10u =$ 1.71

11. The procedure described in § 8 to determine the variability of the parameters with sunspot activity has been followed for the measures of magnetic activity, based on Bartels' measures as given in Table 4 for the entire period of 52 years, 1872-1923. Group I comprises 26 years for which the annual sunspot numbers, S_n, exceed 36; Group II comprises 26 years for which the values of S_n are below 37. The mean epochs, it will be observed from the second column of Table 5 are practically identical for the two groups. For Group I the mean sunspot number, S_{nm}, is 61.2, and the mean value of the magnetic measure, $10u_m$, is 10.18γ; the corresponding values for Group II are $S_{nm}=12.8$, and of $10u_m$, 6.70γ. The values in Table 5 of a_y, $100b_y$, c_y, and r_y were determined by the method of least squares for each group of years.

A comparison of the results for the two groups shows again, by means of a different type of magnetic measure than used in § 8, that

TABLE 5.—*Variability in a_y, b_y, and c_y with sunspot activity of Bartels' magnetic measures, referred to Potsdam (Table 4), 1872-1923.*

Group	T_m	S_{nm}	$10u_m$	a_y	$100b_y$	c_y	r_y
GROUP I (Years of high S_n)	1898.2	61.2	γ 10.18	γ 5.77	γ 7.20	1.25	0.66±0.07
GROUP II (Years of low S_n)	1897.8	12.8	6.70	5.09	12.61	2.48	0.85±0.04
I−II	+0.4	+48.4	+3.48	+0.68	−5.41	−1.23	−0.19

a varies directly, whereas b and c vary inversely, with sunspot activity. So again as *in Table 3, the correlation coefficient is higher for the group of low sunspot activity than for the group of high sunspot activity.*

12. We may also compute a_y and b_y from the differences given in the bottom row of Table 5. Thus

$$b_y = 3.48/48.4 = \overset{\gamma}{0.0719} \tag{7}$$

$$a_y = 6.70 - 12.8\ (0.0719) = 6.70 - 0.92 = \overset{\gamma}{5.78} \tag{8}$$

The values correspond closely with those found for Group I (high S_n), but they differ considerably from the values resulting from Group II.

In a similar manner the values of a_y and b_y may be derived from Table 3, namely:

$$b_y = 4.42/52.5 = 0.0842 \tag{9}$$

$$a_y = 13.11 - 15.4\ (0.0842) = 13.11 - 1.30 = 11.81 \tag{10}$$

Turning to Table 3, it will be seen that these values again agree more closely with those from Group I (high S_n) than for Group II (low S_n).

The *purpose of this section* has been to show that the two methods of computing a and b in the Wolf formula—that of least squares and the group-difference method—yield appreciably different results, even if the series of magnetic measures comprises a large number of years. We are inclined to assign as cause the fact that the Wolf formula is not complete but requires supplementing by a term which takes into account the inter-cycle effect of solar activity.

13. It would appear from Table 2, as already remarked, that we may express the inter-cycle effect, as a first approximation and for the period considered, by a linear term. Accordingly, suppose we first arrange the measures in Table 1 into two groups for which the mean value of S_n will be about the same. Thus we have from Table 1:

Group	Period	S_{nm}	T_m	W_{Dm}
				ϵ
I	1864.5–1891.5	40.9	1878.0	15.75
II	1892.5–1924.5	38.0	1908.5	14.34
		II−I	+30.5	−1.41

Hence, $t = -\overset{\epsilon}{1.41}/30.5 = -\overset{\epsilon}{0.0462} = -0.31$ per cent of W_{Dm}. (11)
The value of t obtained thus is in good agreement with that (−0.0517) found in § 6.

Similarly from Table 4 we have

Group	Period	S_{nm}	T_m	$10u_m$
				γ
I	1873.5–1900.5	35.6	1887.0	8.36
II	1901.5–1923.5	35.8	1912.5	8.19
		II−I	+25.5	−0.17

Hence, $t = -\overset{\gamma}{0.17}/25.5 = -\overset{\gamma}{0.0067} = -0.08$ per cent of $10u_m$. (12)

TABLE 6.—*Values of a_y, b_y, c_y, and r_y according to solar cycles 1878-1922, deduced from the magnetic measures given in Table 4.*

$(Q = 10u = u' = a_y + b_y S_n)$

No.	Period	S_{nm}	$10u_m$	a_y	$100b_y$	c_y	r_y
			γ	γ	γ		
1	1878–1888	34.6	8.26	5.75	7.32	1.27	0.90±0.04
2	1889–1900	38.8	8.62	5.54	7.95	1.44	0.92±0.03
3	1901–1912	31.1	7.56	5.86	5.46	0.93	0.79±0.07
4	1913–1922	44.2	9.14	6.67	5.59	0.84	0.76±0.09

14. The values of the parameters, given in Table 6, were determined for each cycle by the method of least squares, using the data in Table 4. Comparing the values of a_y (Q for $S_n = 0$) in Tables 2 and 6, for the past two cycles, it will be observed that for both sets of magnetic measures, a_y is higher for the cycle 1913-1922, than for the one preceding it. We have here an indication of a reversal in the secular change of the measure of magnetic activity based on the same sunspot number; in brief the sign of t (§§6, 9, and 13) changed from minus to plus during these two cycles. It is chiefly on this account that the shorter series in Table 4 yielded proportionately a smaller value of t (formula 12) than did the longer series in Table 1 (see formula 11).

The values of a'_y (i.e. of $10u_m$ for $S_n = 37.2 =$ mean of S_{nm} for Table 6) are for the successive cycles beginning with 1878-1888: 8.45, 8.49, 7.89 and 8.75γ.

15. Figure 1 is a graphical representation of the data presented in Tables 1 and 4. The upper curve is based on the annual mean values of the Wolf-Wolfer observed relative sunspot numbers, 1856-1925; the second curve represents the most homogeneous

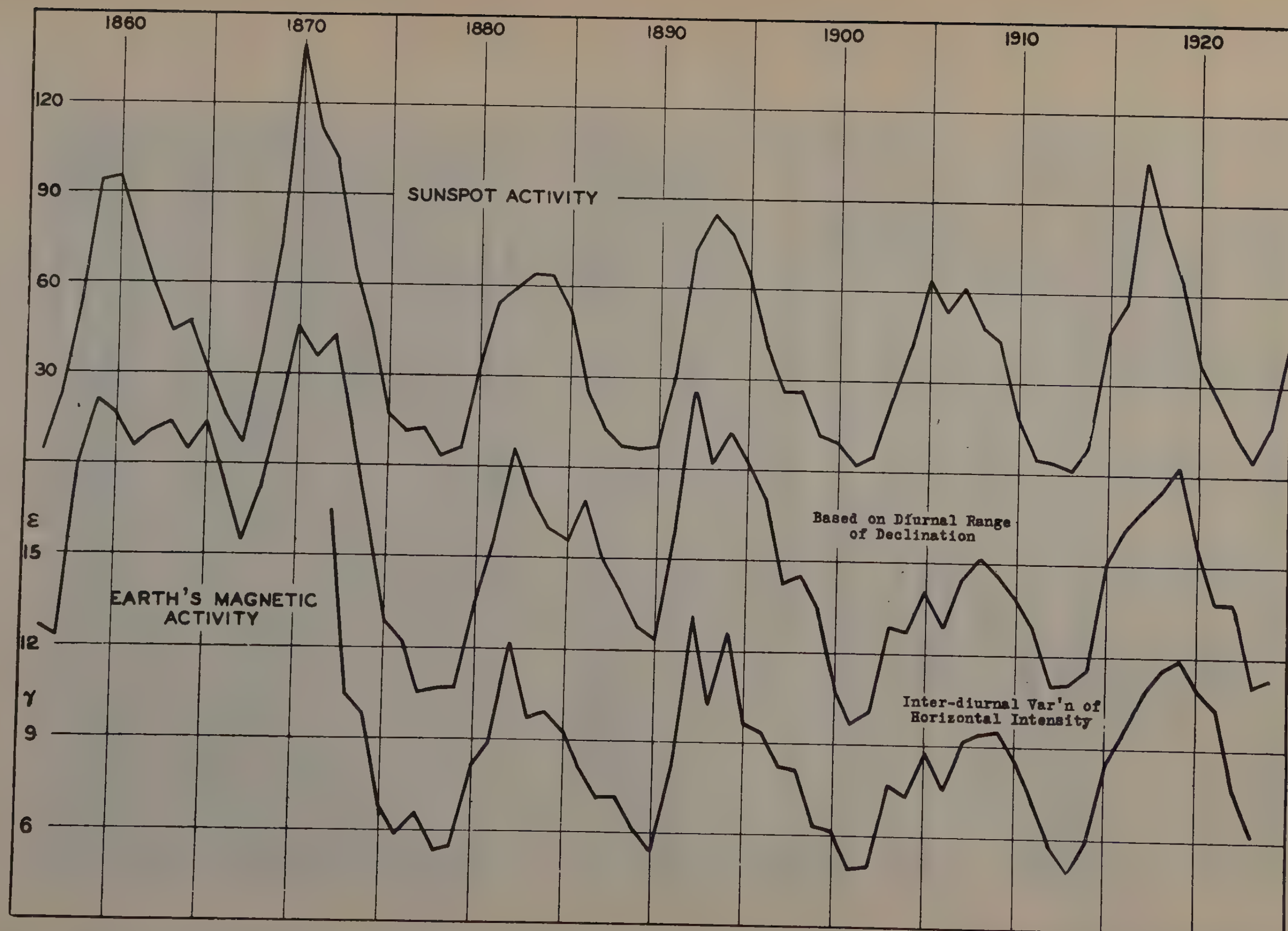

Fig. 1.—The Activity of the Sun (sunspot numbers) and the Activity of the Earth's Magnetism as based upon absolute ranges of the magnetic declination at Kew and Cheltenham, 1856-1924 (Table 1) and upon the

series (Table 1) of measures of magnetic activity at present available and dependent throughout upon *absolute* ranges of the magnetic declination; and the third curve represents a homogeneous series (Table 4) of measures of magnetic activity dependent upon the inter-diurnal differences of the daily means of the horizontal intensity, H. It would be quite possible to extend the curves backward for a number of years. In the case of the curves of magnetic activity, it would be necessary, however, to resort to declination measures made at certain stations at *fixed* hours of each day which yielded diurnal-variation data that are neither absolute ranges nor even daily inequality ranges, as the hours of extreme values of declination vary with season and character of magnetic disturbance. It was with such data, chiefly from Milan, Prague and Christiania that Wolf established correlations with his sunspot numbers; while a very high correlation coefficient, averaging 0.94, is obtained with these, in a certain sense "smoothed" ranges, it is questionable whether their continued utilization will add anything to the *physical* interpretation of the correlation between solar and magnetic activity.

The average value of the correlation coefficient for the magnetic data used in Figure 1, as will be seen from Tables 2 and 6 (last columns) approximates 0.84. While the solar and the magnetic curves follow closely parallel courses, there are also manifest discordances, the study of which it is believed will add more to the physics of the problem than curves which smooth out the discordances (*Cf.* Mɪ, §3.) It is gratifying, however, to note how closely the two magnetic curves, for the common period of observation, agree with one another, even as to details (see formula 6).

It might also be pointed out that while the upper curve of Figure 1 depends alone on phenomena observed on the Sun, the two lower curves depend on magnetic data which are the *combined* effects of systems of magnetic, or electric, forces, both above and below the Earth's surface. Without an harmonic analysis we cannot separate the magnetic effects arising from the external sources from those caused by the internal magnetic systems (electric currents, for example, induced in the Earth).

The magnetic measures for the second curve are expressed in units of ϵ; however as the reduction factor, f of formula 9 (Mɪ, p. 194), for reducing magnetic declination ranges, expressed in minutes of arc to the unit of work, ϵ, approximates to unity for both Kew and Cheltenham, the ordinate scale for this magnetic curve may also be regarded as representing approximately minutes of arc.

The authors again desire to express their appreciation of the substantial assistance received from Mr. C. C. Ennis of the Department of Terrestrial Magnetism, who also prepared Figure 1.

(*To be Continued.*)

Department of Terrestrial Magnetism,
Carnegie Institution of Washington.

LIST OF RECENT PUBLICATIONS

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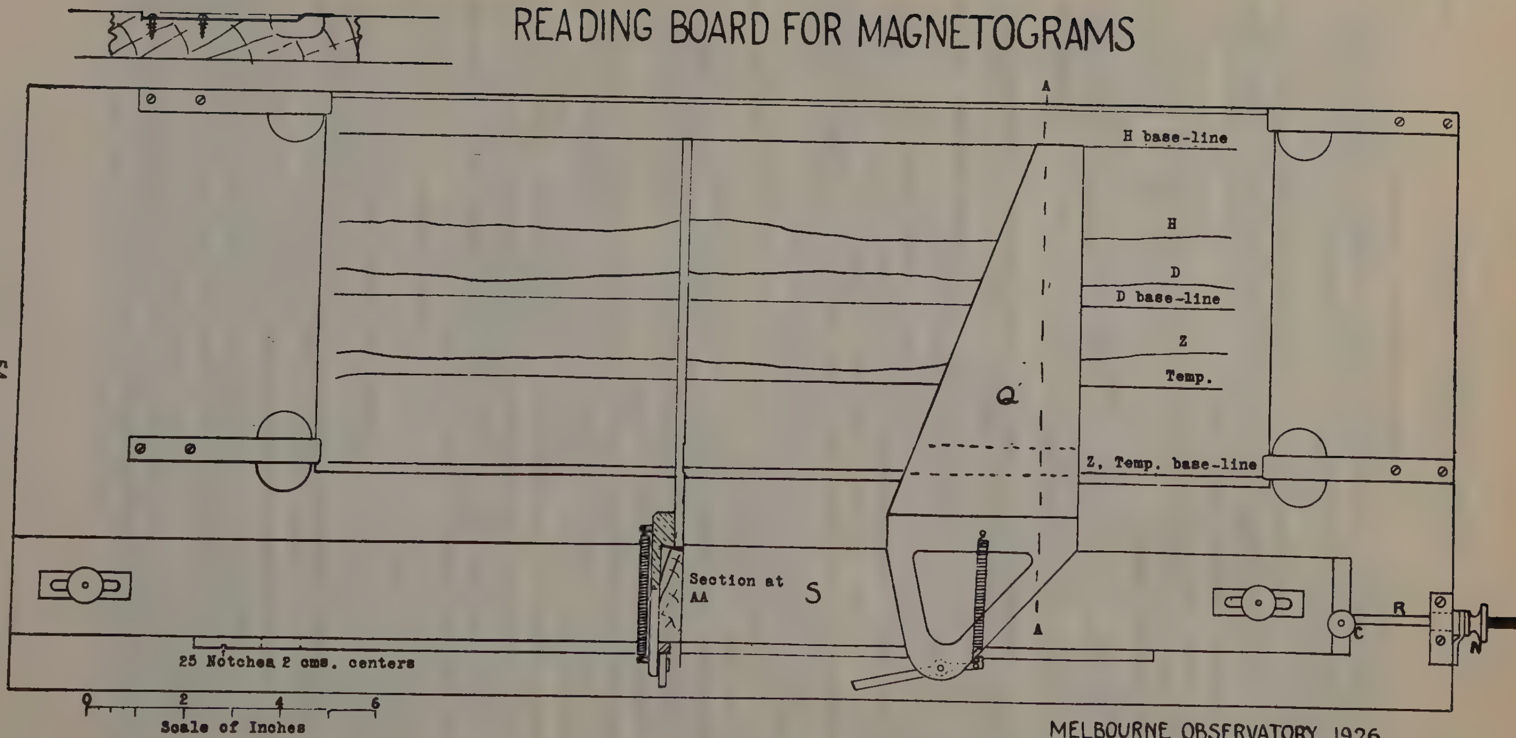

Fig. 1 (see p. 8).

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 31 JUNE, 1926 No. 2

THE 27-DAY RECURRENCY IN EARTH CURRENTS.

BY W. J. PETERS AND C. C. ENNIS.

Dr. Chree and others[1] have shown by statistical investigations the recurrence of average high and average low values on the 27th day after days of selected highest and selected lowest in long unbroken records of magnetic measures, such as the international character numbers and the daily ranges in magnetic elements. The high correlation found by Dr. Bauer[2] between the variations, diurnal and annual, in terrestrial magnetism, atmospheric electricity, and earth-currents indicates the desirability of applying to these related phenomena the same statistical method of searching for a 27-day recurrency.

Accordingly the subject of this paper is a description of the process as applied to the earth-current observations published in the bulletins of the Ebro Observatory in Spain from 1910 to 1924 inclusive and the exhibition of the results.

The daily ranges in the potential of the southerly-extending wire of the earth-current lines, expressed in millivolts per kilometer, had already been found for Dr. Bauer's investigations, so that this preliminary step in the work was not necessary; but for more speed and more flexibility in tabulating, they were all transferred by adding machine to strips of paper, the values following one another throughout the year in regular order without any intermissions, excepting the blank spaces for days on which values are lacking. A strip for one year contains also the values for January of the succeeding year. According to the usual practice the 5 highest and the 5 lowest values of each month were selected and the particular day on which each value occurred was designated n. The values were marked on the strips, after which it became a simple matter to pick out by means of a device designed by Mr. C. C. Ennis,[3] the values that occur on any day desired,

[1] C. CHREE, *Phil. Trans. R. Soc. A*, vol. 212, 1913, pp. 75-116; vol. 213, 1914, pp. 245-277; *Proc. R. Soc. A*, vol. 90, 1914, pp 583-599; vol. 101, 1922, pp. 368-391; vol. 109, 1925, pp. 1-6. A. L. CORTIE, *Proc. R. Soc. A*, vol. 106, 1924, pp. 19-32. J M. STAGG, The absolute daily range of magnetic declination at Kew Observatory, Richmond, *Meteor. Office, Geophysical Memoirs*, No. 29, ninth number of vol. 3, 1926, pp. 252-255; G. ANGENHEISTER, *Terr. Mag.*, vol. 27, 1922, pp. 57-79.

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[3] *Terr. Mag.* vol. 31, 1926, p. 9.

Table 1.—*Ranges in earth-currents (southerly-extending wire) Ebro, 1914. Selected maxima and corresponding values on certain days preceding and following.*
(The unit is millivolt per kilometer.)

n	$n-2$	$n-1$	n	$n+1$	$n+2$	$n+23$	$n+24$	$n+25$	$n+26$	$n+27$	$n+28$	$n+29$	$n+30$	$n+31$	$n+32$
Jan 4	49	41	89	166	34	27	53	22	19	43	26	50	91	80	64
5	41	89	166	34	61	53	22	19	43	26	50	91	80	64	90
14	48	43	84	53	81	90	62	39	25	36	33	41	...	36	42
16	84	53	81	61	34	39	25	36	33	41	...	36	42	...	...
22	37	56	119	35	15	36	42	...	...	65	35	38	...	88	38
Feb 3	26	50	91	80	64	31	29	58	90	94	83	117	42	171	73
4	50	91	80	64	90	29	58	90	94	83	117	42	171	73	40
6	80	64	90	62	39	90	94	83	117	42	171	73	40	62	80
18	..	..	65	35	38	52	64	113	63	113	...	36	69	51	58
22	38	..	88	38	26	113	...	36	69	51	58	60	119	89	60
Mar 4	94	83	117	42	171	80	44	52	66	65	107	50	69	60	53
6	117	42	171	73	40	52	66	65	107	50	69	60	53	259	249
15	52	64	113	63	113	249	125	71	88	80	56	67	54	44	98
17	113	63	113	..	36	71	88	80	56	67	54	44	98	81	60
24	58	60	119	89	60	98	81	60	87	52	74	70	60	58	56
Apr 1	66	65	107	50	69	58	56	60	116	52	53	...	39	61	27
6	60	53	259	249	125	53	...	39	61	27	25	47	73	70	69
7	53	259	249	125	71	...	39	61	27	25	47	73	70	69	78
8	259	249	125	71	88	39	61	27	25	47	73	70	69	78	45
27	56	60	116	52	53	27	44	42	48	43	84	106	...	70	46
May 11	78	45	92	55	68	84	49	53	45	86	71	52	56	61	54
16	39	54	93	88	50	71	52	56	61	54	49	73	82	41	41
17	54	93	88	50	28	52	56	61	54	49	73	82	41	41	37
25	48	43	84	106	..	41	37	108	73	44	57	60	63	113	91
26	43	84	106	..	70	37	108	73	44	57	60	63	113	91	98
Jun 1	63	80	193	68	84	63	113	91	98	147	85	70	44	27	43
19	41	37	108	73	44	63	58	54	41	48	42	51	35	54	83
25	60	63	113	91	98	51	35	54	83	...	...	176	115	112	150
27	113	91	98	147	85	54	83	...	...	176	115	112	150	240	208
28	91	98	147	85	70	83	...	...	176	115	112	150	240	208	155
Jul 5	43	49	236	86	69	240	208	155	161	220	143	186	99	76	110
24	..	..	176	115	112	36	94	85	122	83	56	57	150	...	132
28	112	150	240	208	155	83	56	57	150	...	132	85	82	90	170
29	150	240	208	155	161	56	57	150	...	132	85	82	90	170	...
31	208	155	161	220	143	150	...	132	85	82	90	170	...	77	52
Aug 1	155	161	220	143	186	...	132	85	82	90	170	...	77	52	48
2	161	220	143	186	99	132	85	82	90	170	...	77	52	48	66
3	220	143	186	99	76	85	82	90	170	...	77	52	48	66	...
23	56	57	150	..	132	68	...	...	92	54	63	65	64	170	59
29	82	90	170	..	77	65	64	170	59	58	...	184	...	...	95
Sep 5	66	..	98	72	65	...	...	95	96	110	105	82	...	103	117
9	65	69	140	80	..	110	105	82	...	103	117	70	176	...	...
12	80	..	113	58	45	...	103	117	70	176	...	...	42	...	...
23	65	64	170	59	58	80	...	67	59	52	62	73	...	38	37
27	58	..	184	..	..	52	62	73	...	38	37	34	113	...	210
Oct 2	95	90	110	105	82	37	34	113	...	210	53	52	107	57	122
7	..	103	117	70	176	53	52	107	57	122	147	117	53	94	54
9	117	70	176	..	..	107	57	122	147	117	53	94	54	41	67
27	37	34	113	..	210	71	43	51	43	39	30	32	165	78	50
29	113	..	210	53	52	51	43	39	30	32	165	78	50	115	...
Nov 3	107	57	122	147	117	165	78	50	115	...	40	36	126	54	73
4	57	122	147	117	53	78	50	115	...	40	36	126	54	73	46
5	122	147	117	53	94	50	115	...	40	36	126	54	73	46	61
11	41	67	183	94	53	54	73	46	61	62	141	42	38	63	29
26	30	32	165	78	50	64	45	36	79	35	77	50	33	140	194
Dec 3	40	36	126	54	73	33	140	194	53	126	63	118	31	34	57
9	61	62	141	42	38	118	31	34	57	128	53	84	104	46	37
16	26	37	128	63	42	104	46	37	29	57	108	70	41	45	64
27	50	33	140	194	53	...	...	34	50	...	68	195	134	94	55
28	33	140	194	53	126	...	34	50	...	68	195	134	94	55	55
30	194	53	126	63	118	50	...	68	195	134	94	55	55	66	39
Mean	80	86	139	90	81	74	68	74	77	80	81	80	81	83	80

the $(n+r)$th day, following or preceding the days, nth days, on which the selected values occur. The compilation was arranged as in Table 1, which shows in the 1st and 4th columns, respectively, the dates and corresponding values of the 5 highest values for each month of the year 1914. The remaining columns contain values corresponding to the $(n+r)$th days. The compilation for the lowest values of each month is arranged in the same way. This scheme plans to secure exactly $5 \times 12 = 60$ selected highest values, and 60 selected lowest values for every year, also 60 corresponding values on each of the $(n+r)$th days of the tabulation; but as applied to the Ebro records of earth-currents, this equable distribution for each year is impossible. First, the $(n+r)$th day may be one of the days for which there are no observations. This condition is indicated in the tabulations by a blank space. Second, a number of equal values at times preclude the selection of exactly 5 highest or 5 lowest in one month. More or less must be selected unless an arbitrary choice is made of the two or more days on which the equal values fall which, of course, is very undesirable. In the tabulation for the years, 1910 to 1924 inclusive, this condition is met by taking all the equal values that border the highest or lowest. In Table 1 for the high values of 1914 there are 6 values in the nth column for December, because after selecting the 4 highest values 194, 141, 140 and 128 there remain two equal values, one occurring December 3 and the other December 30. In this particular case it would not have made much difference in the final mean for the 27th day if either one had been arbitrarily chosen and the other ignored since the values on the 27th day are high in both cases, and differ only by 8 units, but in the $(n+26)$th column the difference is 142. Either of these two conditions might be quite serious in some investigations and so these limitations should be considered before applying the method to any series which are incomplete or in which zeros or equal values occur quite frequently.

The values of r were taken from -2 to $+2$ inclusive, in order to bring out the character of the means of the columns adjacent to the selected highest or selected lowest values, and from $+23$ to $+32$ inclusive, not only to show the character of corresponding mean values around the 27th day but also to develop any other recurrency interval that might exist within these limits, such as a 30-day interval similar to the one given for magnetic character numbers by Angenheister[4] or a 31.52 day interval corresponding to the rotational period of the Sun's magnetic axis according to Sears.[5] The mean of each column was taken for each year, for all the years and for various groups of years, in the expectation that if many values go to make up each of the $(n+r)$th columns, the mean of each of these columns will be practically equal, each to each and to the mean as given by the values of every day of the

[4] *Terr. Mag.*, vol. 27, 1922, p. 79.

[5] *Observatory*, vol. 43, 1920, p. 318.

year or group of years unless there is a *frequent recurrence of high values on any particular* $(n+r)$*th day*, in which case the mean value of this particular column will probably exceed materially the mean value as derived from all days of the period. On the other hand a frequent recurrence of low values in any column will probably give a mean value less than the mean of the values of all days. The mean of the 4th column is greater than that of any other column since the values in it are the highest of the various months. In general, high values prevail in column $(n+27)$, but smaller values occur and even the smallest as for October 29 and September 27, after the highest values 210 and 184 in the nth column. This is also true, *mutatis mutandis*, in tables of selected lowest values.

If the dates in the first column are consecutive, values will be repeated in consecutive columns. April 6, 7, and 8 are consecutive in Table 1 for 1914. Thus, the value 53 on the $(n-1)$th day as referred to April 6 is the value on the $(n-2)$nd day as referred to April 7; the value 259 on the nth day referred to April 6 is the value on the $(n-1)$th day as referred to April 7 and the value on the $(n-2)$nd day as referred to April 8 and so on throughout all columns for the same dates. This repetition of values in consecutive columns has a *tendency* to equalize their sums and hence their means. In Table 1 for example, groups of three consecutive days begin April 6, August 1, and November 3. Groups of two consecutive days start January 4, February 3, May 16 and 25, June 27, July 28, and December 27.

Tables 2 and 3 have been derived from the means of the corresponding columns of the tabulation for the year or period of years by subtracting the mean value for the year or period of years as derived from the sum of the values of every day of the year or period of years which each of two groups of columns represents. Thus the yearly mean subtracted from each of the means of columns in the group $n-2$, $n-1$, n, $n+1$, $n+2$ is the mean value derived from the sum of the values for every day of the year from January 1 to December 31; but the yearly mean subtracted from the remaining group of columns is that derived from the sum of the values for every day of the year from February 1 to January 31. The residuals obtained on the nth day of selected highest values and adjacent days form what has been called the *positive* primary pulse; those obtained on the corresponding $(n+27)$th day and adjacent days have been called the *positive* secondary pulse. The *positive* pulses are shown in Table 2. The *negative* pulses, primary and secondary, have been derived in a similar manner from the means of the lowest values and are shown in Table 3.

The pulse differences exhibited in Table 4 are the algebraic differences of corresponding columns of Tables 2 and 3 excepting the last two columns of ratios which will be explained presently. Apparent discrepancies of a unit between the tables are the result of dropping decimals, the original computations having been

TABLE 2.—*Positive Pulses*

	Primary					Secondary										Ratios	
s	$n-2$	$n-1$	n	$n+1$	$n+2$	$n+23$	$n+24$	$n+25$	$n+26$	$n+27$	$n+28$	$n+29$	$n+30$	$n+31$	$n+32$	S/P	S'/P'
0	+3	+13	+62	+20	+5	−4	−10	−5	*+13*	*+13*	+15	0	+4	−4	−5	.21	.43
1	+9	+26	+69	+22	+8	−4	0	+1	*+2*	+16	*+18*	+7	−5	−10	−13	.26	.31
2	−1	+18	+61	+25	+2	−10	−12	+7	*+21*	+19	+7	−4	−10	−4	+6	.31	.46
3	+7	+17	+47	+17	+7	+1	+4	+7	+13	*+14*	*+14*	+12	+3	0	+1	.30	.50
4	+6	+12	+65	+16	+7	−1	−8	−2	+2	+4	*+6*	+4	+6	+7	+4	.09	.13
5	+1	+34	+84	+28	+10	−3	+8	+10	+14	*+33*	+18	+10	+12	+13	+4	.39	.44
6	+10	+37	+100	+39	+12	−6	+3	+8	*+10*	+1	+1	+3	−2	−10	+5	.10	.07
7	−2	+42	+102	+25	+2	−8	−12	−2	+5	*+23*	+2	−4	−16	−4	−10	.22	.17
8	+2	+31	+87	+29	+8	−5	+4	+3	+16	*+24*	+11	+4	+3	0	0	.28	.35
9	+1	+34	+117	+44	+8	−17	−16	−7	+6	*+20*	+14	+4	−5	+3	+2	.18	.21
0	−18	+30	+127	+46	−6	−14	−16	−7	+16	*+34*	+28	−9	−12	−3	+16	.27	.39
1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	...	...
2	+9	+26	+76	+29	+11	−3	−5	+9	+25	*+26*	+20	+16	+3	−10	−8	.34	.54
3	+13	+36	+61	+34	+12	−10	−3	+9	+10	*+15*	+12	+1	−9	−11	−11	.24	.28
4	−4	+13	+57	+17	−2	−1	−6	−4	+9	*+11*	+4	+9	+12	0	0	.20	.27
14	+5	+16	+60	+20	+5	−4	−6	+1	+10	*+12*	+11	+3	0	−2	−2	.20	.35
19	+2	+35	+98	+33	+8	−8	−3	+2	+10	*+20*	+9	+3	−2	0	0	.21	.24
24	+6	+25	+64	+27	+7	−5	−5	+5	+14	*+17*	+12	+9	+2	−7	−7	.26	.37
20	+2	+27	+83	+29	+6	−6	−4	+2	+12	*+19*	+12	+3	−2	0	+1	.23	.31
24	+3	+26	+79	+28	+6	−6	−5	+2	+12	*+18*	+12	+4	−1	−2	−1	.23	.32

TABLE 3.—*Negative Pulses.*

	Primary					Secondary										Ratios	
s	$n-2$	$n-1$	n	$n+1$	$n+2$	$n+23$	$n+24$	$n+25$	$n+26$	$n+27$	$n+28$	$n+29$	$n+30$	$n+31$	$n+32$	S/P	S'/P'
0	−8	−26	−39	−17	−8	0	+3	−2	−5	−6	*−14*	−10	−6	+5	+4	.37	.30
1	−3	−16	−45	−11	+11	+7	−2	−7	−15	*−18*	−3	+7	+14	+15	+15	.40	.50
2	0	−10	−31	−7	−3	+8	+6	*−14*	−5	−2	−1	+4	+6	+5	+4	.46	.15
3	−10	−13	−26	−9	−4	−5	−1	−3	−6	*−10*	−8	−7	−5	−5	0	.40	.53
4	−6	−19	−35	−10	0	−8	−8	−2	0	*−10*	*−10*	−4	−2	−4	−5	.29	.31
5	−3	−20	−51	−22	−4	+1	−10	−8	−11	−7	*−13*	−11	+1	−2	+2	.25	.33
6	−24	−36	−58	−27	−10	+6	+3	−10	−10	*−17*	−15	−14	−10	−10	−4	.30	.35
7	−4	−22	−57	−24	+3	+13	+7	−3	−10	−5	−5	*−17*	+1	+3	0	.29	.20
8	−5	−38	−58	−34	−9	0	−6	*−16*	−15	−14	−12	−2	+10	+7	+18	.29	.31
9	−12	−42	−68	−24	+10	+13	+2	+6	*−4*	+4	+26	+8	+8	−1	−5	.06	.20
0	+3	−24	−61	−10	+18	+17	+12	+4	−7	*−27*	−14	−6	+11	+2	−1	.45	.50
1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	−5	−26	−47	−14	+1	+5	+8	−6	−12	−14	−14	*−17*	−9	+1	+4	.36	.45
3	−12	−19	−33	−14	−3	+3	+4	−5	*−10*	*−10*	−7	−5	+1	+11	+21	.29	.40
4	−5	−15	−34	−13	−2	+5	+5	−8	*−13*	−8	−5	−5	0	+3	−10	.38	.42
14	−6	−18	−35	−11	−2	−1	−1	−6	−6	*−10*	−8	−4	0	+2	+2	.27	.37
19	−10	−32	−58	−26	−1	+7	−1	−7	*−11*	−8	−4	−8	+2	−1	+1	.18	.20
24	−8	−21	−38	−15	−2	+4	+5	−7	*−13*	−11	−9	−8	−4	+5	+4	.33	.45
20	−7	−24	−48	−18	0	+4	0	−5	−9	*−11*	−7	−6	+2	0	+2	.22	.29
24	−8	−24	−46	−18	−1	+4	+1	−6	−10	*−11*	−8	−7	0	+1	+2	.24	.32

TABLE 4.—*Pulse Differences.*

Years	Primary					Secondary										Ra
	$n-2$	$n-1$	n	$n+1$	$n+2$	$n+23$	$n+24$	$n+25$	$n+26$	$n+27$	$n+28$	$n+29$	$n+30$	$n+31$	$n+32$	S/P
1910	+11	+39	+101	+37	+13	− 4	−12	− 3	+18	+19	*+29*	+10	+10	− 9	− 9	.29
1911	+11	+42	+113	+32	− 3	−11	+ 1	+ 8	+18	*+34*	+20	0	−18	−25	−28	.30
1912	− 1	+28	+ 92	+31	+ 5	−18	−18	+21	*+26*	+21	+ 8	− 8	−17	−10	+ 1	.28
1913	+18	+30	+ 73	+26	+11	+ 6	+ 5	+10	+20	*+24*	+22	+19	+ 8	+ 6	+ 2	.33
1914	+12	+31	+100	+27	+ 7	+ 7	0	+ 1	+ 2	+14	*+16*	+ 9	+ 8	+12	+ 9	.16
1915	+ 3	+53	+135	+50	+14	− 3	+17	+18	+25	*+39*	+31	+21	+11	+16	+ 1	.29
1916	+35	+74	+159	+65	+22	−13	0	+19	*+20*	+18	+16	+18	+ 8	0	+ 9	.13
1917	+ 2	+64	+159	+49	− 2	−22	−20	+ 2	+16	*+28*	+ 7	+12	−18	− 7	−10	.18
1918	+ 7	+70	+144	+63	+17	− 5	+10	+19	+31	*+38*	+23	+ 6	− 8	− 8	−17	.26
1919	+14	+75	+185	+68	− 2	−30	−18	−13	+10	*+16*	−12	− 4	−12	+ 4	+ 7	.09
1920	−21	+54	+188	+56	−24	−31	−27	−12	+24	*+62*	+42	− 3	−23	− 5	+16	.33
1921	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1922	+14	+52	+123	+43	+10	− 8	−13	+14	+37	*+40*	+33	+33	+12	−11	−12	.32
1923	+24	+55	+ 95	+48	+15	−13	− 7	+14	+20	*+24*	+19	+ 6	−10	−22	−32	.26
1924	+ 1	+28	+ 92	+30	+ 1	− 6	−11	+ 4	*+22*	+19	+ 9	+14	+13	− 3	+10	.24
1910–14	+11	+34	+ 95	+31	+ 7	− 3	− 5	+ 7	+16	*+22*	+19	+ 7	0	− 4	− 4	.23
1915–19	+12	+67	+156	+59	+ 9	−15	− 2	+ 9	+21	*+28*	+14	+11	− 4	+ 1	− 2	.18
1922–24	+15	+46	+103	+41	+ 9	− 9	−10	+12	+27	*+28*	+21	+16	+ 6	−12	−11	.27
1910–20	+10	+52	+132	+47	+ 6	−10	− 4	+ 7	+20	*+30*	+19	+ 8	− 3	− 1	− 1	.23
1910–24	+11	+50	+125	+46	+ 7	−10	− 5	+ 8	+22	*+30*	+20	+11	− 1	− 3	− 3	.24

carried out to tenths. The mean value for any period is derived from the sum of all the values of that period divided by the number of values in it. Hence the values given for the triennium 1922-1924 for example, might be somewhat different from one-third of the sum of the means for each year of the triennium, since the same number of values does not always occur in each year.

In the column of ratios, S/P represents the maximum value in the secondary pulse divided by the maximum value in the primary pulse. The latter value will always be found in column headed n while the former will be found in the column headed $(n+27)$ or in a neighboring column. The next column headed S'/P', contains the ratios of the sum of the values in columns $n+26$, $n+27$, and $n+28$ to the sum of the values in columns $n-1$, n, and $n+1$.

The following explanatory notes are given for the various groups of years:

1910–14, covers the earliest published records of the Observatory. There are no values for October 1911 and some few other days scattered throughout the pentad.

1915–1919, includes the year of sunspot maximum, 1917, and the year of magnetic maximum, 1919. Two other investigations for this pentad will be described further on.

1922-1924, covers subsequent time, after the intermission of one year, 1921, during which the apparatus was overhauled, up to the most recent published results.

1910–1920, covers the period of still another investigation to be described further on.

1910–1924, includes all data available.

Table 2 shows that in no case has the maximum value of the *positive* secondary pulse occurred before the 26th day or after the 28th day, and out of the 14 years for which the published records are available, the maximum values have occurred 9 times on the 27th day. They have fallen on the 27th day for every one of the last seven years, but this may be entirely fortuitous.

The maximum values for each group of years falls on the 27th day without exception. There is no evidence of a day of recurrency other than the 27th within the limits of the table.

The symmetrical character of the pulses is shown by the relative magnitudes of the values on either side of the maximum. The values on any one line plotted as ordinates to the $(n+r)$ days as abscissae, as in Fig. 1 for the *positive* pulses of the pentad 1915-1919, show graphically the character of the pulses. If a smooth curve be drawn through the indicated points, the crest of the pulse will fall on the $(n+27)$th day provided the adjacent ordinates, those on one side of the $(n+27)$th ordinate are symmetrically arranged and equal to those on the other side. If for example how-

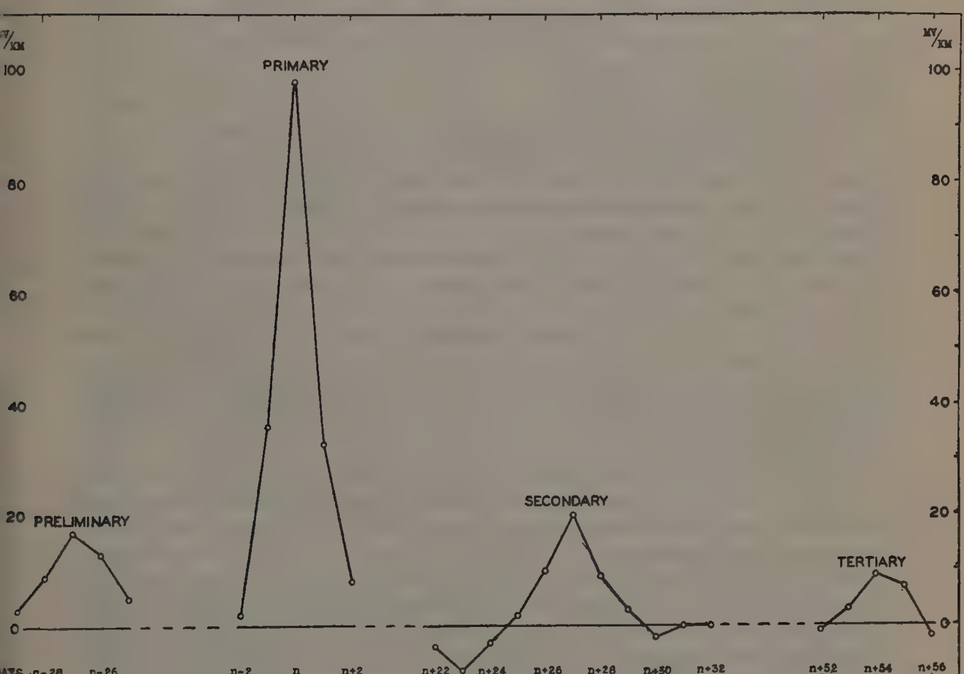

Fig. 1.—Positive Pulses of the Pentad, 1915-1919.

ever, the ordinate on the $(n+26)$th day is larger than that on the $(n+28)$th day the crest will fall between the $(n+26)$th and the $(n+27)$th day. Such considerations have been proposed for determining the fractional part or a day over or less than the interval indicated by the column containing the highest value. They assume however that the primary and secondary pulses are affected alike by secular changes and that other unknown progressive changes have cancelled in the means.

Table 2 shows both the primary and secondary pulses practically symmetrical. The ratio S/P varies from year to year between 0.1 and 0.4, but for a group of years it is about 0.2 or 1/5, practically the same as found by Chree for the international character figures 1906-1920 and for the Kew declination ranges 1858-1900. The ratio S'/P' is larger than S/P in each year except 1916 and 1917. For groups of years it is about 0.3, practically the same as found for the international character figures and Kew declination ranges.

The *negative* pulses in Table 3 are about two-thirds of the magnitude of the *positive* pulses of Table 2, and show more inconsistencies. The minimum values (of the secondary pulses) wander from the $(n+25)$th column to the $(n+29)$th column and for groups of years they may be found in either the $(n+26)$th or the $(n+27)$th columns, although for the two longest periods they are in the $(n+27)$th column. There is also a change of sign in the year 1919, the year of magnetic maximum, on the $(n+27)$th day, the only case of an opposite sign to be found in the 28 of the two tables. There are also greater variations in the two columns of ratios, though the average is about the same as for *positive* pulses.

Table 4 shows the pulse differences. Since the values of this table are obtained by subtracting the corresponding values of Table 3 from the corresponding values of Table 2 they are independent of the two means, one for $(n-2)$ to $(n+2)$ columns, the other for $(n+23)$ to $(n+32)$ columns used for each year or period of years in deriving the pulses from the preliminary tabulation. As in Table 2, the maximum values of the secondary pulse do not occur before the $(n+26)$th day nor after the $(n+28)$th day in any one year; moreover for the different periods of years the maximum value occurs on the 27th day. The symmetry of the difference pulses is not so good as that for the *positive* pulse, yet it is better than for the *negative*.

Dr. Chree extended his investigations of the international magnetic character numbers to include also the values around the 54th day and the 81st day after the nth day of highest and lowest values and also around the 54th day and 81st day preceding the nth day. He found *positive* and *negative* pulses in every case corresponding respectively to the *positive* and *negative* primary pulses. The pulses about the 81st day before and after the nth day were the smallest, those about the 54th were next in amplitude, on the 27th day before and after they were still larger, while on the nth day of course they were largest.

For the Ebro earth-currents this investigation has included values around the 54th day after the *n*th day and around the 27th day before the *n*th day, for the pentad 1915–1919. The results are given in Tables 5 and 6 respectively. The pulses have been derived in the same manner as for Tables 2, 3 and 4 except that the year is considered as beginning March 1 in getting the mean value for the secondary pulse in Table 5 and as beginning December 1 in getting the secondary pulse in Table 6. The primary pulses remain the same as under their respective headings in Tables 2, 3, and 4.

Table 5 shows more wandering from year to year of the maximum values of the tertiary pulses, both *positive* and *negative*, than appears in Tables 2, 3, and 4, for the secondary pulses, but for the whole pentad the maxima appear in the $(n+54)$th column.

The columns of ratios show the amplitude of the tertiary pulse to be about 1/8 of the primary.

The maximum values of the preliminary pulses around the 27th day before the *n*th day, Table 6, are found not earlier than the 29th day before nor later than the 26th day before the *n*th day in any one year. For the whole pentad the maximum values are in the

TABLE 5.—*Pulses on or about the following 54th day.*

Years	Primary					Tertiary					Ratios	
	$n-2$	$n-1$	n	$n+1$	$n+2$	$n+52$	$n+53$	$n+54$	$n+55$	$n+56$	S/P	S'/P'
					Positive Pulse							
1915	+ 1	+34	+ 84	+28	+10	+12	+ 9	+ 6	+17	*+19*	.22	.22
1916	+10	+37	+100	+39	+12	− 5	+ 3	*+ 5*	0	− 4	.05	.05
1917	− 2	+42	+102	+25	+ 2	− 1	− 4	*+10*	+ 3	− 3	.10	.05
1918	+ 2	+31	+ 87	+29	+ 8	− 1	+ 9	*+16*	+ 4	−19	.19	.20
1919	+ 1	+34	+117	+44	+ 8	−10	− 1	*+11*	*+11*	− 4	.09	.11
1915–19	+ 2	+36	+ 98	+33	+ 8	− 1	+ 3	*+ 9*	+ 7	− 2	.10	.12
					Negative Pulse							
1915	− 3	−20	− 51	−22	− 4	− 8	− 7	−10	*−12*	−11	.23	.31
1916	−24	−36	− 58	−27	−10	+ 4	0	*−17*	−16	− 1	.29	.27
1917	− 4	−22	− 57	−24	− 3	+ 6	+ 3	− 2	− 6	*− 8*	.14	.05
1918	− 5	−38	− 58	−34	− 9	− 4	*−13*	−12	−11	− 5	.21	.28
1919	−12	−42	− 68	−24	+10	*− 6*	+ 1	− 3	+ 9	+12	.09	−.05
1915–19	−10	−32	− 58	−26	− 1	− 2	+ 3	*− 9*	− 8	− 3	.16	.12
					Pulse Differences							
1915	+ 3	+53	+135	+50	+14	+20	+16	+16	+29	*+30*	.22	.26
1916	+35	+74	+159	+66	+22	− 9	+ 2	*+22*	+16	− 3	.14	.14
1917	+ 2	+64	+159	+49	− 2	− 6	− 7	*+12*	+ 9	+ 5	.08	.05
1918	+ 7	+70	+144	+63	+17	+ 3	+22	*+28*	+15	−14	.19	.24
1919	+14	+75	+185	+68	− 2	− 5	− 2	*+14*	+ 2	−16	.08	.04
1915–19	+12	+67	+156	+59	+ 9	+ 1	+ 6	*+18*	+15	+ 1	.12	.14

TABLE 6.—*Pulses on or about the preceding 27th day.*

Years	Primary					Preliminary					Ratios	
	$n-2$	$n-1$	n	$n+1$	$n+2$	$n-29$	$n-28$	$n-27$	$n-26$	$n-25$	S/P	S'/P'
						Positive Pulse						
1915	+ 1	+34	+ 84	+28	+10	+11	*+21*	+17	+ 8	+13	.25	.31
1916	+10	+37	+100	+39	+12	*+15*	+14	*+15*	+13	+ 2	.15	.24
1917	− 2	+42	+102	+25	+ 2	0	+14	*+18*	+11	− 3	.18	.25
1918	+ 2	+31	+ 87	+29	+ 8	−12	−10	+15	*+20*	+ 4	.23	.18
1919	+ 1	+34	+117	+44	+ 8	0	+ 4	*+20*	+14	+ 7	.17	.19
1915–19	+ 2	+36	+ 98	+33	+ 8	+ 3	+ 9	*+17*	+13	+ 5	.17	.23
						Negative Pulse						
1915	− 3	−20	− 51	−22	− 4	− 6	−10	*−24*	−13	+ 3	.46	.50
1916	−24	−36	− 58	−27	−10	−13	*−21*	− 4	+ 2	0	.35	.19
1917	− 4	−22	− 57	−24	+ 3	+ 2	− 2	*−17*	−11	+ 8	.30	.29
1918	− 5	−38	− 58	−34	− 9	− 6	− 1	− 4	*− 9*	− 4	.16	.11
1919	−12	−42	− 68	−24	+10	0	*−19*	− 5	− 3	+23	.28	.20
1915–19	−10	−32	− 58	−26	− 1	− 4	−11	*−12*	− 7	+ 6	.20	.25
						Pulse Differences						
1915	+ 3	+53	+135	+50	+14	+17	+31	*+40*	+21	+10	.30	.39
1916	+35	+74	+159	+66	+22	+28	*+35*	+19	+11	+ 2	.22	.22
1917	+ 2	+64	+159	+49	− 2	− 2	+16	*+35*	+21	−11	.22	.27
1918	+ 7	+70	+144	+63	+17	− 6	− 8	+19	*+29*	+ 8	.20	.14
1919	+14	+75	+185	+68	− 2	0	+23	*+25*	+17	−16	.13	.19
1915–19	+12	+67	+156	+59	+ 9	+ 8	+20	*+28*	+20	− 2	18	.24

$(n+27)$th column. The average ratio of these preliminary pulses to the primary are almost as large as the average ratio of the secondary to the primary.

Fig. 1 shows the 4 *positive* pulses developed by the investigation for the pentad 1915–1919. It is possible that other pulses can be developed on or about the 81st day both before and after the nth and also about the 54th day before the nth day, but the time and personnel available have not been sufficient to develop them or fill in the hiatus between pulses.

The *negative* pulses for the same pentad would show practically the same general features inverted about the horizontal base.

The nth day is not a tangible date available for predicting, nor does there appear to be any time relation between the nth day of highest values and the nth day of lowest values. It is quite natural to look for some relation between the *positive* pulse and the *negative* pulse just as one looks for the trough to follow at a fixed interval after the crest or for a minimum half way between two maxima. If low values did occur on the average a certain fixed number of days after or before the highest values, this interval could be derived *either from the highest or the lowest values* by extending the

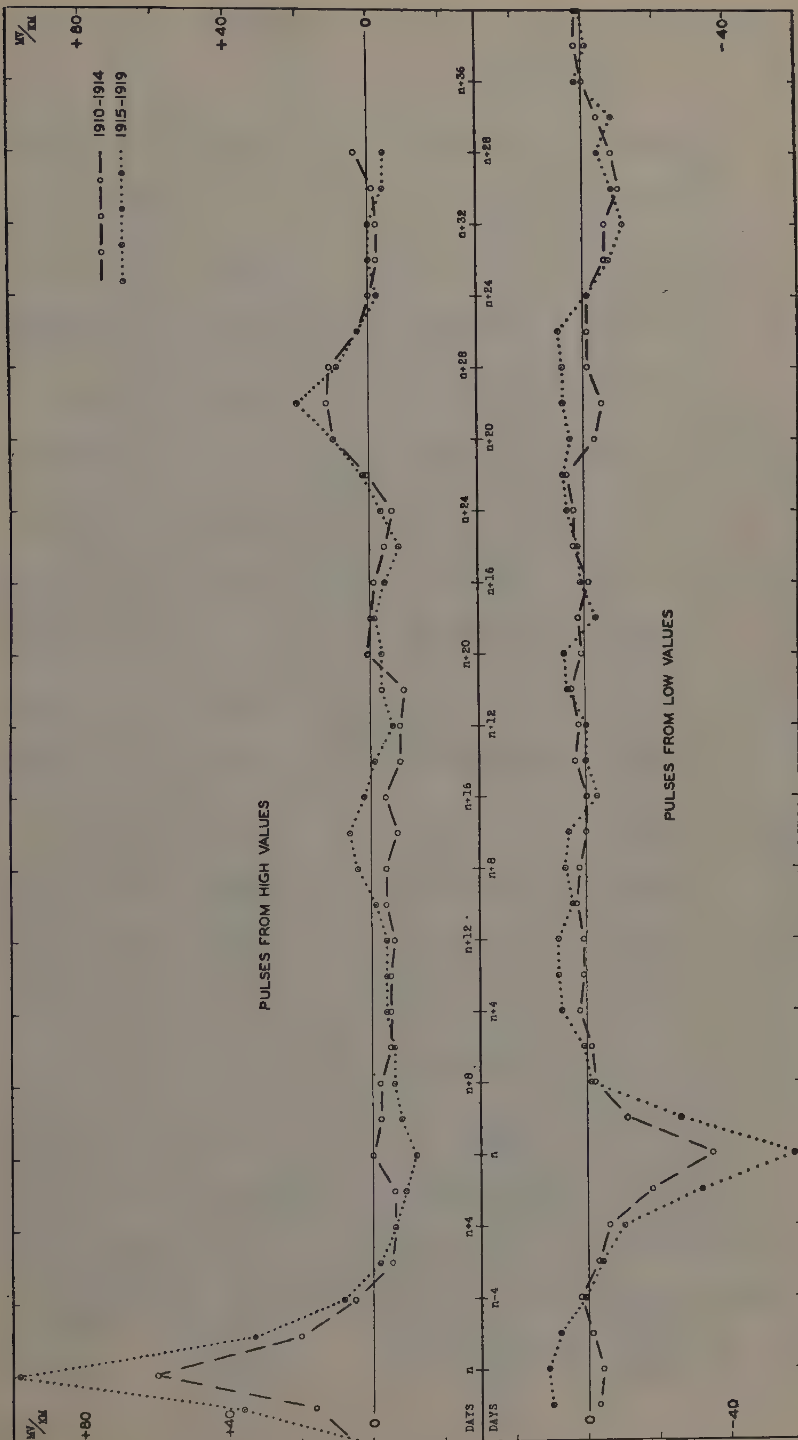

Fig. 2.—Positive and Negative Pulses for the Pentads, 1910-1914 and 1915-1919.

TABLE 7.—*Residuals in millivolts per kilometer for all days from $n-2$ to $n+34$ and from $n-7$ to $n+32$ showing the pulses as derived from the 5 highest and the 5 lowest values respectively.*

Pulses depending on 5 highest selected values.

Years	$n-7$	$n-6$	$n-5$	$n-4$	$n-3$	$n-2$	$n-1$	n	$n+1$	$n+2$	$n+3$	$n+4$	$n+5$	$n+6$	$n+7$	$n+8$	$n+9$	$n+10$	$n+11$	$n+12$	$n+13$
1910–14	.....	.....	.....	.....	.....	+5	+16	+60	+20	+5	−5	−6	−6	0	−2	−2	−5	−5	−5	−6	−4
1915–19	.....	.....	.....	.....	.....	+2	+36	+98	+33	+8	−2	−6	−9	−12	−8	−6	−6	−4	−4	−4	−1
1910–19	.....	.....	.....	.....	.....	+4	+27	+80	+28	+7	−3	−5	−7	−6	−4	−4	−4	−3	−4	−4	−2

Years	$n+14$	$n+15$	$n+16$	$n+17$	$n+18$	$n+19$	$n+20$	$n+21$	$n+22$	$n+23$	$n+24$	$n+25$	$n+26$	$n+27$	$n+28$	$n+29$	$n+30$	$n+31$	$n+32$	$n+33$	$n+34$
1910–14	−4	−7	−4	−8	−8	−9	+1	0	−1	−4	−6	+1	+10	+12	+11	+3	0	−2	−2	−1	+4
1915–19	+4	+6	+2	−1	−6	−3	−3	−1	−4	−8	−3	+2	+10	+20	+ 9	+3	−2	0	0	−4	−4
1910–19	+1	0	0	−4	−6	−6	−1	0	−2	−5	−3	+3	+11	+18	+11	+4	0	0	0	−1	+1

Pulses depending on 5 lowest selected values.

Years	$n-7$	$n-6$	$n-5$	$n-4$	$n-3$	$n-2$	$n-1$	n	$n+1$	$n+2$	$n+3$	$n+4$	$n+5$	$n+6$	$n+7$	$n+8$	$n+9$	$n+10$	$n+11$	$n+12$	$n+13$
1910–14	−3	−4	−1	+2	−3	−6	−18	−35	−11	−2	−1	+2	+1	+1	+3	+2	0	0	+3	+2	+4
1915–19	+10	+11	+8	+1	−4	−10	−32	−58	−26	−1	+1	+7	+8	+8	+4	+6	+5	−3	0	0	+5
1910–19	+4	+4	+4	+2	−3	−8	−24	−48	−19	−2	0	+4	+4	+5	+4	+4	+3	−1	+1	+1	+4

Years	$n+14$	$n+15$	$n+16$	$n+17$	$n+18$	$n+19$	$n+20$	$n+21$	$n+22$	$n+23$	$n+24$	$n+25$	$n+26$	$n+27$	$n+28$	$n+29$	$n+30$	$n+31$	$n+32$	$n+33$	$n+34$
1910–14	+1	+2	−1	+3	+3	+5	−3	−5	−1	−1	−1	−6	−6	−10	−8	−4	0	+2	+2	.....	.....
1915–19	+6	−3	+1	+2	+5	+6	+4	+6	+6	+7	−1	−7	−11	−8	−4	−8	+2	−1	+1	.....	.....
1910–19	+3	0	+1	+3	+5	+6	+1	0	+3	+3	−1	−6	−9	−9	−6	−6	+1	0	+2	.....	.....

investigation to include all the necessary values of r in tabulating the $(n+r)$ columns. This extension was undertaken, first for the pentad 1915–19 and subsequently for the pentad 1910–14. Results are given numerically in Table 7 and graphically in Figure 2. The two dotted lines representing the pulses derived respectively from the selected highest values and from the selected lowest values for the pentad 1915–19 confirm each other in showing a time interval of about 6 days between primary pulses which persists, though less distinctly in the secondary pulses. That is, the dotted line derived from the highest values shows a negative pulse of 12 millivolts per kilometer amplitude, 6 days after the primary positive pulse and a slight negative pulse of 4 millivolts per kilometer amplitude, 6 days after the secondary positive, while the dotted line derived from the lowest value shows a positive pulse of 11 millivolts per kilometer 6 days after the primary negative pulse and a positive pulse of 6 millivolts per kilometer 5 or 6 days before the secondary negative pulse. The scale of days corresponding to the selected lowest values has been advanced 6 days over the scale of days corresponding to the selected highest values so as to bring the apparently corresponding pulses one over the other.

These rather remarkable coincidences encouraged further investigation and the extension was made to include the preceding pentad, the results for which give the two broken lines. Here there is repudiation of a 6-day interval rather than confirmation and a line (not shown) representing the results for the decennium, obviously, would be nearer straight between pulses than those of Fig. 2. It will be interesting to see whether observations of future years will confirm the non-existence of a time relation between positive and negative pulses or the existence of an approximately six-day interval.

The process of this investigation involves the selection of a certain arbitrarily chosen number, 5 of the highest values and 5 of the lowest values in an arbitrarily chosen period of time, namely one month. The question has been asked what would be the result if some other quota had been selected? Partly in answer to this question, partly to search for a recurrency after several consecutive high and low values on the assumption that *consecutive* high and *consecutive* low values represent greater activity and therefore would more likely show larger pulses in 27 days, a separate investigation was made according to the following scheme. Beginning with 1910 and ending in 1924 and running from year to year without regard to the end of the year, every 40 values of the daily ranges, already impressed upon the adding machine strips, were indicated by drawing demarcation lines. The ten highest values of each one of these groups of 40 were marked, and from these ten highest only consecutive values of 3 or more were selected as the values of the nth day. From this step on the tabulations and calculations were carried on as already described.

The result is indicated by the ratio of the secondary pulse to

the primary pulse, S/P, which is 0.25. The ratio given in Table 2 is 0.23. It appears, therefore, that these two differently selecting methods at least, give practically the same result.

Conclusions.

a. In the process of tabulation, it was quite obvious (see Table 1 for example,) that all the highest values and all the lowest values of the daily range in earth-currents are *not* followed 27 days later by high and low values respectively, although this frequently happens, but the investigation has shown that the high and low values that follow, fall on and around the 27th day in such a way that the mean value for a number of years on the 27th day after the highest values is a high value and the mean value on the 27th day after the lowest values is a low value. And this is true also as regards the 54th day and probably the 81st day after the highest and lowest values respectively but with diminishing numerical values. That is, these subsidiary pulses following the primary pulse at intervals of 27 days gradually fade somewhat like damped oscillations. There are also preceding pulses beginning probably 81 days before the primary which increase at each repetition in every 27 days.

b. The recurrency on the 54th day and the symmetry about the 27th day are in harmony in showing that the interval of 27 days has been determined within an uncertainty of ½ day for the *positive* pulse, but such accord is not found for the *negative* pulse.

c. If the recurrency of 27 days approximately, be associated with the rotational period of the Sun, the increasing amplitudes of the preliminary pulses and the waning amplitudes of the subsequent pulses might be ascribed to an increasing activity followed by a decreasing activity of points or portions of the Sun which each successive revolution of approximately 27 days brings to a position favorable for causing high or low values of the daily ranges. Another explanation might be that there are more points or parts of the Sun in which the activity lasts only through one revolution than there are points or parts in which activity persists for several revolutions. Such uneven distribution would throw more extreme values in the $(n+27)$th columns than in the $(n+54)$th columns or the $(n+81)$st columns. There are, however, no such individual points or places of activity that can be identified at present with any visible manifestations of solar activity of a particular date.[1]

d. The mutually independent character of the positive and negative pulses with respect to time, if confirmed by future observations, might be ascribed to solar activity above normal and below normal respectively, so distributed over the Sun's surface with respect to time of occurrence and place (solar longitude) that there are no fixed differences in the times of occurrences nor any fixed differences in the solar longitudes of the places or points of activity respectively above and below normal.

[1] L. A. BAUER AND C. R. DUVALL, *Terr. Mag.*, vol. 30, 1926, p. 213.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE APIA OBSERVATORY, JANUARY TO MARCH, 1926

(*Latitude, 13° 48′.4 S.; longitude, 171° 46′, or 11*^{h} *27*^{m}*.1 W. of Greenwich.*)

Greenwich Mean Time						Range		
Beginning			Ending			Decl'n	Hor. Int.	Vert. Int.
1926	h	m	d	h	m	′	γ	γ
Jan. 26	16	18	27	4	..	15.8	255	75
Feb. 23	16	24	25	5	..	7.5	170	not measured
Mar. 5	10	04	6	12	..	6.0	135	not measured

January 26-27, 1926.—This storm is remarkable for the large number of rapid motions up and down shown on the horizontal-intensity magnetogram. Maxima and minima sometimes follow one another at extraordinarily short intervals. A conspicuous example of this occurs at 23^{h} 53^{m}, when the value changes from 35166γ to 35293γ, a rise of 127γ in 7 minutes. Then the curve immediately turns back again and returns to 35178γ, a fall of 115γ, again in 7 minutes. The curve is even steeper than this at 17^{h} 57^{m}, where a fall of 92γ is registered in two minutes (35253γ to 35161γ), and several other instances of movements not much less rapid could be mentioned. There are two maxima and minima which are conspicuous among the extreme values recorded, namely: January 25, 16^{h} 28^{m}, $H=35317\gamma$ and $Z=20488\gamma$; January 25, 18^{h} 40^{m}, $H=35104\gamma$ and $Z=20420\gamma$; January 26, 0^{h} 04^{m}, $H=35293\gamma$ and $Z=20496\gamma$; January 26, 1^{h} 12^{m}, $Z=20435\gamma$; January 26, 2^{h} 23^{m}, $H=35062\gamma$. The end of the violent disturbance is at 4^{h}, but there is still some milder disturbance after this time.

March 5, 1926.—The sudden commencement is shown well. The horizontal-intensity curve is descending quietly, and is deflected sharply upward at 10^{h} 03^{m} 48^{s}.

April 14-15, 1926, preliminary note.—The following approximate measurements of this storm are available at present, just as the mail is closing: Sudden commencement at 14^{d} 14^{h}, exactly under hour-mark; maximum horizontal intensity at 14^{d} 14^{h} 20^{m} is 35260γ; minimum horizontal intensity at 15^{d} 7^{h} 30^{m} is 34930γ. At 15^{d} 15^{h} the curve returns to normal and is only lightly disturbed, but further disturbance sets in on the next magnetogram, which is not yet available for measurement.

(The negative sign of Z is disregarded, as usual in our reports to facilitate tabulation.)

ANDREW THOMSON, *Director;* C. J. WESTLAND, *Observer.*

APIA OBSERVATORY,
WESTERN SAMOA, APRIL 17, 1926.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE SITKA MAGNETIC OBSERVATORY, JANUARY TO MARCH, 1926.[1]

(Latitude 57° 03′.0 N.; longitude 135° 20′.1, or 9^h 01.3^m W. of Greenwich.)

Greenwich Mean Time								Range		
Beginning				Ending				Decl'n	Hor. Int.	Vert. Int.
1926		h	m	1926		h	m	′	γ	γ
Jan.	13	3	..	Jan.	16	19	..	57.0	370	415
Jan.	18	8	..	Jan.	20	6	..	58.9	294	465
Jan.	22	15	34	Jan.	23	24	..	51.6	458	443
Jan.	26	16	19	Jan.	28	4	..	201.3	1392**	713*
Feb.	23	16	28	Feb.	25	14	..	232.9*	1394*	787*
Mar.	5	10	04	Mar.	6	12	..	209.9*	1259*	655*
Mar.	9	11	..	Mar.	12	2	..	86.5	650	449
Mar.	17	21	04	Mar.	19	6	..	61.1	644	549

F. P. Ulrich, *Observer-in-Charge.*

*Denotes plus readings.
**Denotes plus readings for both maximum and minimum.
[1] Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

PROVISIONAL SUNSPOT NUMBERS FOR APRIL AND MAY, 1926.

Day	Apr.	May	Day	Apr.	May
1	35	62	17	69	65?
2	30	53	18	63	71
3	29	56	19	75	80
4	29	68	20	58	63
5	22	86	21	41	75
6	23	53?	22	35	67
7	30	74	23	14?	40
8	27	102	24	14	27
9	49	92	25	16	31
10	29	88	26	..	22
11	34	93	27	14	23
12	37	89	28	19	43
13	58	..	29	41	54
14	71	60?	30	39	52
15	65	86	31	..	50
16	69	84	Mean for month	39.1	63.6

Zürich, April 30 and May 31, 1926. A. Wolfer.

PRINCIPAL MAGNETIC STORMS RECORDED AT ANTIPOLO, RIZAL, NEAR MANILA, P. I., JANUARY TO MARCH 1926.

(*Latitude 14° 35′ 48″ N.; longitude 121° 10′ or 8^h 04.^{m}7 E. of Greenwich.*)

Greenwich Mean Time							Range		
Beginning			Ending				Decl'n	Hor. Int.	Vert. Int.
1926	*h*	*m*	*d*	*h*	*m*		′	γ	γ
Jan. 26	16	18	27	3	34		6.0	319	64
Feb. 23	16	22	24	20	42		5.9	291	46

Besides the above, minor disturbances occurred as follows: January 18 at 9^h to January 19 at 4^h; January 22 at 15^h 37^m to January 23 at midnight; February 17 at 15^h 36^m to February 18 at 5^h; March 5 at 10^h 10^m to March 6 at noon; March 9 at 5^h 26^m to March 10 at 8^h 30^m; and March 11 at 0^h to March 12 at 4^h 40^m.

PHILIPPINE WEATHER BUREAU,
MANILA, P. I.

M. SADERRA MASÓ,
Chief, Seismic and Magnetic Divisions.

REQUEST FOR LITERATURE ON ATMOSPHERIC ELECTRICITY.

We are planning to write an extensive treatise on atmospheric electricity which will be published next year.

On account of the well-known shortage of funds of the libraries in Austrian Universities, it is extremely difficult for us to obtain foreign journals, especially the bulletins and proceedings of scientific institutions and societies in foreign countries.

It would be a great help in our work if physicists and meteorologists in all English-speaking countries would kindly send us reprints of their publications pertaining to Atmospheric Electricity (Electric Field of the Earth and Atmosphere, Ionization of the Atmosphere, Thunderstorm Electricity, Electrical Properties of Rain and Snow, Radioactivity of the Earth and Atmosphere, Rays of Cosmic Origin, Electric Currents in the Atmosphere, Polar Lights, Theories of the Origin of Atmospheric-electric Phenomena, Propagation of Electric Waves around the Earth).

All colleagues who are willing to assist us are asked to send reprints of their publications to the following address:

PHYSIKALISCHES INSTITUT,
UNIVERSITÄT, GRAZ, AUSTRIA.

PROF. H. BENNDORF AND PROF. V. F. HESS.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE WATHEROO MAGNETIC OBSERVATORY FOR JANUARY TO MARCH, 1926.

(Latitude, 30° 19′.1 S.; longitude, 115° 52′.6 or 7ʰ 44ᵐ E. of Greenwich.)

Greenwich Mean Time						Range		
Beginning			Ending			Decl'n	Hor. Int.	Vert. Int.
1926	h	m	d	h	m	′	γ	γ
Jan. 22	15	35	23	23	58	19.1	132	97
Jan. 26	3	43	29	17	56	....	378	...
Jan. 26	3	44	29	17	55	42.2	...	...
Jan. 26	3	45	29	17	56	....	...	158
Feb. 17	14	49	18	6	25	....	...	88
Feb. 17	14	49	18	6	26	21.6	128	...
Feb. 23	16	25	25	14	43	....	253	...
Feb. 23	16	26	25	13	41	24.2	...	178
Mar. 5	10	04	6	22	22	29.2	...	142
Mar. 5	10	04	6	22	23	....	167	...
Mar. 9	5	10	12	9	18	....	...	109
Mar. 9	5	11	12	9	23	21.2	...	...
Mar. 9	5	12	12	9	23	....	156	...

January 22-23 and January 26-29, 1926.—Notes on these storms are given on pages 23 to 25 of the March 1926 number of this Journal.

February 17 to 18, 1926.—This disturbance was of comparatively short duration, the most noteworthy feature being its oscillatory nature. From 22ʰ 17ᵐ, February 17, to 5ʰ 38ᵐ, February 18, oscillations of varying amplitude and period occurred, the amplitude from 4ʰ 28ᵐ to 5ʰ 38ᵐ becoming abruptly smaller and finally merging into the normal condition.

February 23 to 25, 1926.—This storm was by far the most violent that has been experienced at this Observatory for some time. It was characterized by a sudden commencement at 16ʰ 25ᵐ on February 23. This was 28 days and 8 minutes after a very abrupt commencement of a movement during the storm of January 26 to 29. During the commencement, the horizontal intensity increased by 53 gammas in 4 minutes, the corresponding changes in the first two minutes for declination and vertical intensity being 2.3 minutes of arc and 6 gammas, respectively. The storm can be divided into four phases, each of which is fairly sharply defined from its predecessor. The first phase continued till 20ʰ 39ᵐ on February 23, when its large and relatively slow movements were supplanted by quick oscillations. This second period changed to one of large rapid motions at 10ʰ 26ᵐ, February 24, and continued till 21ʰ 45ᵐ of the same day, when the worst of the storm appeared to be over. The fourth period was one of slow recovery to slightly sub-normal conditions.

During both of the above storms the telegraphic system of the State of Western Australia was affected. The Deputy Postmaster General at Perth states that the telegraphic system was considerably affected by earth-currents of an alternating nature, these having a period on February 18 and on February 26 of 15 seconds between their maxima and minima with a variation of current strength from +10 milliamperes to −3 milliamperes.

The month of March, as a whole, was generally disturbed; there were two disturbances of considerable magnitude, the principal features of which were as follows:

March 5-6, 1926.—This moderate storm was characterized by a very definite sudden commencement, consisting of a very rapid downward movement followed by another of almost equal rapidity in the opposite direction. The changes in the elements for the first oscillation were $4'.4$, 10γ, and 10γ in an interval of 40 seconds, and for the second oscillation $4'.6$, 55γ, and 8γ in an interval of 90 seconds for declination, horizontal intensity, and vertical intensity, respectively, these values being slightly uncertain as the movement of the recording beam of light was so rapid as to barely leave a mark on the record. This preliminary movement was followed by a series of sharp bays and peaks, the absolute value falling almost continually until 20^h March 5, when a recovery set in. Oscillatory perturbations manifested themselves from 0^h to 9^h March 6, when the elements gradually became quieter. Subnormal conditions then prevailed until approximately 23^h March 6, and indeed for a day or two subsequently.

March 9-12, 1926.—No particularly outstanding features attached to this storm, which began with a very mild sudden commencement and then became gradually more and more disturbed. At about 16^h March 9 considerable movement of the horizontal-intensity trace occurred, a series of sharp bays and peaks continuing for approximately two hours. At about 20^h deep depressions occurred in all three traces. Subsequently the horizontal-intensity and vertical-intensity ordinates became very low, and all three elements exhibited comparatively short-period oscillations. Shortly after 8^h March 10 all values suddenly increased appreciably and decreased again, horizontal intensity by a small amount only; for horizontal intensity, therefore, the net result was a sudden increase in ordinate. From this time slightly disturbed conditions prevailed, horizontal intensity being generally subnormal.

All times given are Greenwich mean time.

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PRINCIPAL MAGNETIC STORMS RECORDED AT THE HUANCAYO MAGNETIC OBSERVATORY FOR JANUARY TO MARCH, 1926.

(Latitude 12° 02.′7 S.; longitude 75° 20.′4 W. or 5^h 01^m W. of Greenwich.)

Greenwich Mean Time			Range		
Beginning		Ending	Decl'n	Hor. Intens.	Vert. Intens.
1926	h m	d h m	′	γ	γ
Jan. 22	15 36	24 Indefinite.	13.1	Off Sheet	47
Jan. 26	15 31	27 1 approx.	18.5	Off Sheet	49
Feb. 23	16 ..	24 21 approx.	9.3	Off Sheet	38
Mar. 5	10 04	5 22 approx.	17.5	388	49
Mar. 9	11 36	10 5 approx.	9.1	452	42

January 13, 1926. This is not strictly a magnetic storm. There are two sudden commencements of interest. The first began at 19^h 40^m and in ten minutes the H trace had dropped 71γ. There followed a period of normalcy and at 20^h 39^m another sudden commencement in which the H decreased 85γ in twelve minutes, when it left the sheet and apparently continued its abrupt downward movement for some minutes, returning to registration approximately 30 minutes after leaving the sheet.

January 14, 1926. This is not strictly a magnetic storm. There are two sudden commencements of interest. The first began at 14^h 18^m and in eleven minutes the H trace had increased 99γ. There followed a period of normalcy and at 14^h 53^m another sudden commencement in which the H decreased 160γ in fourteen minutes.

January 18, 1926. This day is normal except for a sudden commencement in H in the form of a 118γ drop, beginning at 14^h 38^m and ending at 14^h 42^m. The D and Z traces show changes of 2.′2 and 5γ respectively.

January 22-24, 1926. This prolonged disturbance in all three elements began at 15^h 36^m January 22 with a sudden commencement in H in the form of a 137γ increase in three minutes. At the same time D decreased 3.′3 and Z, 12γ. From the beginning of the storm to 2^h January 23 all three elements experienced abrupt increases and decreases. At 2^h January 23 all three elements became more stable and H was markedly subnormal. During the daylight hours of January 23 and 24 all three curves are characterized by bays and peaks and H more particularly by elongated saw-tooth formations. The ending of the disturbance is indefinite.

January 26-27, 1926. A general disturbance in all three elements began at 15^h 31^m. In H the beginning was marked by an abrupt increase of 95γ in eleven minutes. The D and Z traces are characterized by bays and peaks to the end of the storm which occurred at approximately 1^h January 27. The rapidity and

magnitude of the H movements makes further scaling details impossible.

February 23-24, 1926. Although there is no marked beginning, the disturbance becomes abnormal between 16^h and 17^h February 23. The disturbance is characterized by bays and peaks in D and Z and by elongated saw-tooth formations in H. The storm continues to 21^h February 24, being of much greater intensity during the daylight hours. The following sudden commencements in H are recorded as characteristic of the disturbance.

Beginning			*Ending*		*Time Range*	*γ Range*
	h	m	h	m	m	
February 23	18	56	19	17	21	321 decrease
February 23	20	01	20	10	9	258 increase
February 24	14	05	14	17	12	232 increase
February 24	15	20	15	33	13	330 decrease
February 24	15	40	15	56	16	351 increase

March 5-6, 1926. The storm began abruptly in all three elements at 10^h 04^m March 5 and lasted approximately to 22^h March 5. The disturbance is characterized by bays and peaks in D and Z and by elongated saw-tooth formations in H. On March 6 the three elements are more normal but apparently undergoing the after effects of the storm rather than a continuation of it. During the daylight hours of March 5 there are numerous sudden commencements in H of large magnitude. The following are the two most prominent.

Beginning			*Ending*		*Time Range*	*γ Range*
	h	m	h	m	m	
March 5	17	37	17	46	9	215 increase
March 5	17	48	17	57	9	234 decrease

March 9-10, 1926. This storm shows a well defined beginning at 11^h 36^m March 9 in both D and H. There is no distinct beginning in Z. The D and Z traces are characterized by bays and peaks and the H by elongated saw-tooth formations. The storm ends at approximately 5^h March 10.

All times given are Greenwich civil mean time.

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DIE ELEKTRISCHE LEITFAEHIGKEIT DER ATMOSPHAERE UND IHRE URSACHEN.[1]

Vorwort.

Seit dem letzten Erscheinen von grösseren zusammenfassenden Darstellungen der atmosphärischen Elektrizität in deutscher Sprache, nämlich der Monographien von A. Gockel (1908) und von H. Mache und E. v. Schweidler (1909) sind fast zwei Jahrzehnte verflossen. Der Fortschritt, der in dieser Zeit erzielt worden ist, ist durchaus vergleichbar mit jenem in der Zeit von 1899 bis 1909, in der die Anwendung der Lehre von den Gasionen und der Nachweis der radioaktiven Substanzen im Erdboden, in den Gewässern und in der Atmosphäre der luftelektrischen Forschung neue Wege wies.

Unsere Kenntnisse von der Elektrizitätsleitung der Atmosphäre sind wesentlich erweitert und vertieft worden. Die luftelektrischen Verhältnisse über dem Ozean haben durch die ausgedehnten Forschungsfahrten der Carnegie-Institution von Washington in allen Meeren volle Klärung gefunden. Auf Ballonfahrten in Europa hat man eine neue Quelle der Ionisation gefunden, eine von oben her die Erdatmosphäre durchsetzende Strahlung hoher Penetrationskraft, die sogenannte Höhenstrahlung. Die Wirkung dieser und der übrigen ionenbildenden Faktoren an der Erdoberfläche und innerhalb der ersten zehn Höhenkilometer der Luft (Troposphäre) sind nun auch quantitativ ziemlich gut bekannt.

Ueber die höheren atmosphärischen Schichten, in denen sich die Nordlichterscheinungen abspielen, und deren ausserordentlich hohe elektrische Leitfähigkeit für die Ausbreitung der Wellen der Radiotelegraphie und -telephonie von grundlegender Bedeutung ist, hat man von verschiedenen Seiten her neue Erkenntnisse gewonnen.

Andererseits hat auch die Erforschung der Wiedervereinigung von Ionen, also der „ionenvernichtenden Prozesse" grosse Fortschritte erzielt. Es ist so möglich geworden, wenigstens für die Troposphäre ein in sich geschlossenes Bild von der mittleren Wirksamkeit der ionenerzeugenden und ionenvernichtenden Vorgänge in quantitativer Uebereinstimmung mit der Erfahrung zu geben, wenn man auch noch weit davon entfernt ist, alle Einzelheiten in den regelmässigen Schwankungen der Leitfähigkeit, der Ionisation usw. erklären zu können.

Gerade weil dieses Teilgebiet der atmosphärischen Elektrizität wenigstens in groben Zügen zu einem gewissen Abschluss gelangt ist, schien es mir wünschenswert, in der vorliegenden Schrift eine Darstellung des gegenwärtigen Standes unserer Kenntnisse über die Ionisation der Atmosphäre und ihre Ursachen zu geben.

Das vorliegende Werk wendet sich an einen weiteren Leser-

[1] Sammlung Vieweg, vol. 84, 1926; 170 pp.

kreis: Freunde der Geophysik, der Meteorologie, speziell der Aerologie, dann der Radiotelegraphie und -telephonie, der Geologie und der Astronomie, ferner Elektrotechniker, Seeleute, Luftschiffer und auch allgemein gebildete Laien werden, wie ich hoffe, in dem Buche manches Anregendes finden. Für den weiteren Leserkreis sind die einführenden Abschnitte über die Lehre von den Gasionen, die Stromleitung in Gasen und über die Grundlehren der Radioaktivität an passender Stelle eingefügt. Soweit als möglich sind in den einzelnen Abschnitten die Methoden und die Beobachtungsergebnisse getrennt dargestellt.

Die Literaturangaben sind hinsichtlich der wichtigeren neuen und der grundlegenden älteren Arbeiten ziemlich vollständig, um dem Leser die Möglichkeit zu geben, sich in Spezialfragen zu vertiefen. Doch musste natürlich davon abgesehen werden, minder wichtige Arbeiten und Beobachtungsergebnisse zu zitieren.

Eine ausführliche Bibliographie soll in einem breiter angelegten Werke über das Gesamtgebiet der atmosphärischen Elektrizität, das von Professor Dr. Hans Benndorf (Graz) und mir geplant ist, und das im gleichen Verlage erscheinen wird, geboten werden.

Es ist mir eine angenehme Pflicht, den Fachkollegen, die mich durch Uebersendung von Sonderabdrücken, briefliche Mitteilungen und Ratschläge gefördert haben, an dieser Stelle meinen herzlichsten Dank abzustatten: so vor allem Dr. Louis A. Bauer, Direktor des Departments of Terrestrial Magnetism der Carnegie-Institution in Washington, D. C. (U. S. A.), Professor Dr. A. Gockel in Freiburg (Schweiz), Professor A. F. Kovarik (New Haven), Professor Dr. E. Schweidler (Innsbruck) und Professor Dr. A. Wigand (Stuttgart-Hohenheim).

VICTOR F. HESS.

Graz (Steiermark), Physik. Inst. d. Universität, im Februar 1926.

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UEBER DIE URSACHE DER SCHWANKUNGEN DES LUFTELEKTRISCHEN POTENTIALGEFAELLES.

Von A. Gockel.

Inhaltsangabe.—In einer früheren Arbeit hat der Verfasser die Frage untersucht, ob der Zusammenhang zwischen Sonnentätigkeit und den Aenderungen des elektrischen Erdfeldes ein direkter sein kann, vermittelt durch eine von der Sonne ausgehende Strahlung oder ein indirekter hervorgerufen dadurch, dass die Sonnenflecken die meteorologischen Faktoren und damit die Leitfähigkeit der Atmosphäre ändern. Die erstere Auffassung scheint die wahrscheinlichere.

Der Potentialgradient hängt ab von 2 unabhängigen Variabeln, dem Luft-Erdstrom und der Leitfähigkeit. Der erstere ist durch kosmische, die letztere durch meteorologische Faktoren beeinflusst. Wo sich die Leitfähigkeit der Atmosphäre wenig ändert, folgt der Verlauf des P. G. dem des Stromes. Dieser hat eine regelmässige tägliche, jährliche und säkulare Schwankung. Der Zusammenhang tritt am deutlichsten hervor in der Arktis, der Antarktis und auf den Ozeanen. An andern Orten, an denen die Leitfähigkeit stark schwankt, wird der Verlauf des Luft-Erdestromes ein unregelmässiger. Die 24 Stundenwelle des Potentialgradienten ist hauptsächlich durch den kosmischen Faktor beeinflusst, der sich nach Universalzeit ändert; die 12-stündige durch Aenderungen der Leitfähigkeit, also meteorologische Vorgänge, die von der Lokalzeit abhängen.

Abstract.—In a previous paper the author investigated the problem whether the relation existing between solar activity and variations of the Earth's electric field, caused by radiation proceeding from the Sun, is a direct relation or whether, because of the fact that sunspots produce changes in meteorological factors which in turn affect the conductivity of the atmosphere, the relation is an indirect one. It would appear that the former assumption is the more probable.

The potential gradient depends upon two independent variables, the air-earth current and the conductivity. The former is influenced by cosmic factors and the latter by meteorological. In the event where the conductivity of the atmosphere varies little, the course of the potential gradient follows that of the current. This current has a regular diurnal and annual variation and changes in the course of a sunspot cycle. This relation is most clearly evident in the Arctic and Antarctic regions and on Oceans. In other places where the conductivity varies strongly, the course of the air-earth current becomes irregular. The 24-hour wave of the potential gradient is influenced chiefly by the cosmic factor; this factor varies with universal time. The 12-hour wave is caused by the variations of the conductivity and also of other meteorological occurrences which are dependent on local time.

Durch die Untersuchungen von Louis A. Bauer ist zum mindesten für einige Stationen sicher gestellt, dass ein Zusammenhang zwischen den Jahresmitteln der Sonnenfleckentätigkeit und denen des Potentialgefälles besteht und dass auch die mittlere Amplitude der täglichen Schwankung des P. G. eine Abhängigkeit von der Sonnentätigkeit zeigt. In einer Arbeit, die an einem andern Orte erscheint,[1] habe ich die Frage behandelt, ob dieser Einfluss der Sonnenflecken als ein direktor oder indirekter aufgefasst werden kann, d.h. ob anzunehmen ist, dass eine von der Sonne ausgehende Strahlung direkt das elektrische Feld der Erde ändert, oder ob die Sonnentätigkeit zunächst die Luftdruckverteilung über der Erde und damit die Windrichtung an der betrachteten Station ändert,

[1] A. Gockel, *Gerlands Beiträge zur Geophysik*, 13 and 15, 1926.

wodurch dann Aenderungen in der Leitfähigkeit und damit auch des elektrischen Erdfeldes hervorgebracht werden. Diese Untersuchungen haben mich zu der Ansicht geführt, dass eine indirekte Beeinflussung des Erdfeldes wenig wahrscheinlich ist. Es sprechen mehr Gründe dafür, dass zum mindesten neben den etwaigen indirekten auch eine direkte Beeinflussung des elektrischen Erdfeldes durch die Sonnentätigkeit vorhanden ist. Aber auch diese kann zweierlei Art sein: Entweder die von der Sonne ausgehende Strahlung ändert die Ionisation der Atmosphäre. Ist der Strom, der von dieser zur Erde fliesst, annähernd konstant, so muss jede Aenderung der atmosphärischen Leitfähigkeit das P.G. ändern. Oder man kann annehmen, dass von der Sonne direkt elektrische Ladungen in der Form von α- oder β-Strahlen auf die Erde, oder in die Atmosphäre gesandt werden, welche das elektrische Erdfeld ändern.

Ich habe mich früher zu Gunsten der ersteren Auffassung ausgesprochen, habe an derselben Stelle aber auch auf die Schwierigkeiten hingewiesen, welche dieser Auffassung entgegenstehen.[2] Vor allem sind die Schwankungen der Leitfähigkeit weniger regelmässig als die des P.G. und ein Einfluss der Sonnentätigkeit ist schwerer zu erkennen. Ein Einfluss des *Sonnenlichtes* ist in der Troposphäre auch nicht möglich. Ferner, bei Bestimmungen der Ionisierungsstärke, ausgeführt durch Messungen der Intensität des Sättigungsstromes in einem vor jedem Versuch mit frischer Luft gefülltem Gefäss, zeigte es sich, dass die zeitlichen Schwankungen des ionisierenden Faktors 10% seines Mittelwertes kaum überstiegen. Grösser, aber klein gegenüber den Schwankungen des ionenverzehrenden Faktors, fand sie früher v. Schweidler.[3] Die Annahme, dass das Potentialgefälle sich in der Weise ändere, dass das Produkt P.G. mal Leitfähigkeit einen *konstanten* Strom liefert, scheint mir daher wenig wahrschenich, richtiger erscheint mir die Annahme, dass auch der Strom veränderlich ist. Das Potentialgefälle ist dann, wie dieses auch schon früher v. Schweidler auseinandergesetzt hat, bestimmt durch zwei von einander unabhängige Faktoren, nämlich den seiner Natur nach uns noch unbekannten Strom, der negative Elektrizität zur Erde oder positive in die Atmosphäre schafft, und der nur von meteorologischen Faktoren abhängigen Leitfähigkeit. Wäre erstens der Luft-Erdestrom, den wir allein messen können, dem Zustrom stets gleich, und zweitens die Leitfähigkeit konstant, so müssten sich für das P.G. einfache Gesetze ergeben.[4] Nun sind diese beiden Bedingungen aber im allgemeinen nicht erfüllt: die erste vielleicht deshalb nicht, weil es die zweite nicht ist. Nach den Betrachtungen Benndorfs[5] müssen auch nur die Mittelwerte von Luft-

[2] A. Gockel, *Physikal. Zeitschr.* **24**, 590, 1923. Dieselben Ansichten auch bei Markgraf, *Meteor. Zeitschr.* **41**. 65, 1924.

[3] v. Schweidler, *Sitzber. Wiener Akademie*, **127**, 953, 1918 u. **128**, 947.

[4] Ich verstehe unter dem Luft-Erdestrom stets den gemessenen Strom, also einen Ionenstrom, während der im entgegengesetztem Sinne laufende Zustrom wahrscheinlich ein Elektronenstrom ist.

[5] H. Benndorf, Sitzber Wiener Akademie **134**, 281, 1925.

Erdestrom und Zustrom einander gleich sein. Wo sich aber die Leitfähigkeit der Atmosphäre wenig ändert, wird der Verlauf des Potentialgefälles dem des Zustromes annähernd parallel gehen, und es ergeben sich dann eine Reihe einfacher Beziehungen.

1. S. J. Mauchly hat gefunden, dass auf den Ozeanen, über denen die elektrische Leitfähigkeit der Atmosphäre sich im Laufe des Tages wenig ändert, die 24-stündige Welle des P.G. sich nicht nach Lokalzeit sondern nach Universalzeit ändert. Dieses Resultat der Beobachtung erklärt sich durch die Annahme, dass diese Welle verursacht wird durch Schwankungen des Zustromes, die sich über der ganzen Erde gleichzeitig vollziehen. Die 12-stündige Welle muss dagegen herrühren von Schwankungen der Leitfähigkeit. Diese werden ihrerseits verursacht durch meteorologische Faktoren wie Temperatur und relative Feuchtigkeit, die sich mit der Lokalzeit ändern. Es ist ja auch schon lange bekannt, dass die Amplitude der 12-stündigen Welle mit der Entfernung vom Erdboden abnimmt.

2. In der Antarktis ist der jährliche Gang des P.G. gleichsinnig mit dem in der Arktis. Auf beiden Halbkugeln fallen die Maxima des P.G. in den Dezember oder Januar, die Minima in den Juli; der meteorologische Charakter der Jahreszeit ist also ohne Einfluss. Dasselbe gilt nach den Beobachtungen der Carnegie Institution auf den Ozeanen auch für weniger hohe Breiten.[6] Des weiteren fand Hoffmann,[7] dass für die arktischen und antarktischen Gegenden dasselbe gilt, was Mauchly für die Ozeane gefunden hat, dass nämlich die täglichen Schwankungen an allen Orten gleichmässig verlaufen, wenn man sie nicht nach Lokalzeit sondern nach Universalzeit anschreibt. „Die jährlichen und täglichen Extremwerte des P.G. treten also in der Arktis und Antarktis zu gleichen absoluten Zeiten auf." Nun hat aber ebenfalls Hoffmann in Eboltofthafen auf Spitzbergen (79° n. B.) gefunden, dass die tägliche und jährliche Schwankung der Leitfähigkeit dort geringer ist als in unseren Beiten. Es beträgt die jährliche Schwankung auf Spitzbergen, wenn man von einigen ganz aus der Reihe fallenden Werten im August absieht, 28% des Mittelwertes. in Davos dagegen 60%. Die tägliche Schwankung der Leitfähigkeit betrug im Mittel der ganzen Registrierperiode (November bis August) 11% des Mittelwertes, während sie in Davos auf 130 und in einigen Monaten sogar auf über 160% ansteigt. Die geringen Schwankungen der Leitfähigkeit auf Spitzbergen bewirken, dass das P.G. dem Zustrome folgt.

3. Anders liegen die Verhältnisse dort, wo die Leitfähigkeit starken Aenderungen unterworfen ist. Auch nach den Rechnungen von Benndorf wirkt eine Aenderung der Leitfähigkeit wie eine solche des Zustromes, der Verlauf des P.G. kann also nicht dem des wirklichen Zustromes parallel gehen. Schon in weniger hohen

[6] Louis A. Bauer, Sunspot and annual variations of atmospheric electricity, with special reference to the *Carnegie* observations, 1915-1921. Publication No. 175, Carnegie Institution of Washington, 1926, pp. 382-384.

[7] K. Hoffmann, *Beiträge zur Physik der freien Atmosphäre*, **11**, 1, 1923.

Breiten kommen grössere Schwankungen der Leitfähigkeit vor. In Karasjok (69° n. B.) fand Simpson die jährliche Schwankung der λ über 70% des Mittelwertes. Die tägliche konnte, weil nur 3 mal im Tage gemessen wurde, nicht bestimmt werden.

Aus den von Dorno auf Seite 144 und 145 seiner Studie über Licht und Luft des Hochgebirges veröffentlichten Kurven ergibt sich sehr schön, dass das vormittägige Maximum des P.G. verursacht ist durch ein tiefes Minimum der Leitfähigkeit, herrührend vom Aufsteigen der Dunstschichten aus dem Talboden. Dagegen entspricht dem gegen 19 ^{h}M.E.Z. auftretenden Maximum des P.G. keine oder eine nur sehr schwache Abnahme der Leitfähigkeit. Wie die Gleichzeitigkeit dieses Maximums mit dem von der Carnegie Expedition auf dem Meere beobachteten zeigt, ist es nicht durch lokale Vorgänge sondern durch das um diese Zeit überall auftretende Maximum des Vertikalstromes bedingt.

Auch in dem in der ungarischen Tiefebene gelegenen Kalocsa beträgt, wenigstens in den Monaten August und September, für die allein Messungen vorliegen, die Amplitude der täglichen Leitfähigkeitschwankungen nur etwa 40% des Mittelwertes;[8] daher überwiegt im Gange des P.G. auch hier die einfache vom Zustrom abhängige 24-stündige Welle mit einem Maximum gegen Abend. In Kew dagegen schwankten die Monatsmittel der mit dem Wilsonschen Apparat gemessenen Leitfähigkeit in den Jahren 1909 bis 1912 zwichen 0.079 und 0.565×10^{-6} E.S.E., das sind 163% des Mittelwertes,[9] infolgedessen verläuft auch die jährliche Schwankung des Luft-Erdestromes ganz unregelmässig. In München dagegen, wo die Schwankung der Monatsmittel der Leitfähigkeit auch noch 124% des Mittelwertes beträgt, kommt wenigstens das Juli Minimum und Januar Maximum des Stromes klar zur Erscheinung. In Eskdalemuir schwankt die Stärke der Ionisation merkwürdig wenig zwischen Winter und Sommer, infolgedessen zeigen auch die von Dobson veröffentlichen Kurven einen glatteren Verlauf als die von Kew.

In seiner Studie über Licht und Luft des Hochgebirges teilt Dorno die monatlichen Stundenmittel des Luft-Erdestromes mit und zwar erstens berechnet aus Normaltagen und zweitens aus allen niederschlagsfreien Stunden. An Normaltagen fallen die Maxima zwischen 23^h u. 4^h G.Z., im Mittel aller niederschlagsfreier Stunden dagegen wie auf den Meeren auf die späten Nachmittagsstunden. An den Normal- d.h. heiteren Tagen überwiegt eben der Einfluss der Bewegung der Dunstschichten, u. der Gang des Luft-Erdestromes wird abhängig von den dadurch hervorgebrachten Aenderungen der Leitfähigkeit. An den Tagen mit stärkerem Wind tritt dieser Einfluss zurück, u. der Luft-Erdestrom folgt dem Zustrom. Man sieht nebenbei bemerkt, dass die so häufig angewandte Auswahl von „Normaltagen" die wirklichen Verhältnisse verschleiern kann.

[8] A. Wagner, Wiener Ber. 118, 1625, 1909.
[9] G. Dobson, Geophysical Memoirs, No. 7.

4. Nach dem, was ich hier auseinandergesetzt habe, ist der häufig in der Literatur vorkommende Satz: Der Strom folgt dem Potentialgefälle, nicht richtig. Es muss statt dessen heissen, das P.G. folgt dem Strome. Von diesem ist schon lange bekannt, dass er örtlich und zeitlich eine ziemlich grosse Konstanz aufweist. Wäre der Luft-Erdestrom immer gleich dem Zustrome, so müsste er sich an allen Orten gleichmässig u. nach einfachen Gesetzen ändern. Das ist im allgemeinen nicht der Fall, der Strom zeigt auch eine Abhängigkeit von den sich unregelmässig ändernden meteorologischen Faktoren. Die Aufrechterhaltung des elektrischen Erdfeldes verlangt, dass der Luft-Erdestrom áuch innerhalb eines kleinen Zeitraumes der Erde ebenso viel positive Elektrizität zuführt, wie der Zustrom negative. Zwei Gründe bewirken, dass diese Forderung trotz der beobachteten Unregelmässigkeiten des Vertikalstromes erfüllt ist. Erstens, die ungefähre Konstanz der Ladungsdichte an einem Punkte der Erde kann auch durch einen Strom innerhalb der Erde aufrecht erhalten werden. Ein Zusammenhang zwischen dem luftelektrischen P.G. und den Erdströmen ergibt sich nach den Untersuchungen L.A. Bauers aus den Beobachtungen in Tortosa. Zweitens folgt aus Ballonmessungen Wigands, dass der Strom nicht, wie man früher angenommen hatte, längs eines Vertikalschnittes durch die ganze Troposphäre konstant ist, sondern dass in der Atmosphäre auch Anhäufungen freier Ladungen vorkommen können. Auf das Vorhandensein von Potentialgefällsprüngen an den Grenzen von Dunstschichten hatten früher schon Elster u. Geitel u. Linke hingewiesen. Die Notwendigkeit von Aenderungen der Stromstärke längs einer Vertikalen ergibt sich schon aus den Beobachtungen in Bodennähe. Hier in Freiburg ist innerhalb einer von NE kommenden Luftströmung der Vertikalstrom stärker als in einer von SW kommenden. An andern Orten scheint das, wenn man aus dem Verhalten des P.G. auf den Strom schliessen darf, ebenfalls der Fall zu sein. Fliesst nun z. B. ein SW Wind über einem aus NE kommenden, so muss sich an der Grenze beider Luftströmungen ein Ueberschuss negativer Elektrizität einstellen. u. umgekehrt, wenn der NE Wind der obere ist. Vielleicht hängen damit die von Herath[10] beobachteten raschen Potentialgefälleschwankungen an solchen Trennungsschichten zusammen. Verursacht wird die Verschiedenheit der Stromstärke in den beiden Luftströmungen offenbar durch die Unterschiede der Leitfähigkeit, welche in der SW Strömung grösser ist.

Dort wo die Leitfähigkeit wenig schwankt, ist auch der Verlauf des Vertikalstromes ein regelmässiger. Nach den Beobachtungen der Carnegie Expedition tritt auf den Meeren im täglichen Verlauf fast überall ein Minimum gegen 5^h, ein Maximum gegen 19^h, im Sommer etwas später, mittlerer G.Z. auf. Messungen, die erlauben dieses Resultat auch für andere Orte nachzuprüfen,

[10] Fr. Herath, *Zeitschr. f. techn. Physik*, **4**, 116, 1923, und *Die Naturwissenschaften*, **12**, 141, 1924.

liegen leider nur in geringer Zahl vor. Von Davos habe ich schon oben gesprochen. In Potsdam ist nur das abendliche Maximum gut zu erkennen. An beiden Orten weist die Leitfähigkeit im Laufe des Tages starke Schwankungen auf. Nach Registrierungen Simpsons in Simla, die sich aber nur über 3 Wochen erstreckten, fällt das Maximum des Stromes auf 15^h G.Z., nach ebenfalls kurz dauernden von Berndt in Argentina auf 16^h G.Z. Dass der Strom an so weit von einander entfernten Orten nach Universalzeit einen ähnlichen Gang aufweist, ist immerhin bemerkenswert. Die von P. Huber in Altdorf (in der Nähe des Vierwaldstättersees) ausgeführten Messungen, die ich an anderer Stelle[11] besprochen habe, zeigen an einigen Tagen sehr schön den auf dem Meere konstatierten Gang des Vertikalstromes. Auch hier in Freiburg ist das um 19^h M.E.Z. eintretende Maximum des Stromes in der Regel sehr deutlich ausgeprägt, wenn auch sekundäre Maxima, die durch Aufsteigen von Dunstschichten hervorgerufen werden, häufig überwiegen. Messungen von P. Stutz, im letzten Jahre nach der Wilsonschen Methode ausgeführt, die sich auch über die Nacht ausdehnen, lassen auch das morgendliche Minimum erkennen.

Auch für die Feststellung des jährlichen Ganges des Vertikalstromes liegt nur wenig Material vor. In Tortosa, wo der Luft-Erdestrom täglich einmal, 11^h gemessen wird, ist die Periode aber sehr schön ausgeprägt. Die folgenden Zahlen geben den Durchschnitt der Jahre 1911-24.

Jan.	Feb.	März	Apr.	Mai.	Juni	Juli	Aug.	Sept.	Okt.	Nov.	Dez.
3.12	2.94	2.98	2.93	2.43	2.34	2.25	2.32	2.73	2.90	3.09	3.44

Meine eigenen früheren Messungen ergeben im dreijährigen Durchschnitt ein Minimum im Mai oder Juni, ein Maximum in Februar. Die neueren Messungen von P. Stutz lassen dagegen bis jetzt keinen ausgesprochenen Jahresgang erkennen. Auch in Kew lässt sich nur feststellen, dass der Strom im Winter in der Regel stärker ist als im Sommer ebenso in Davos. Dagegen ist in Potsdam nach den Registrierungen des P.G. u. der negativen Leitfähigkeit der Jahresgang des Stromes in guter Uebereinstimmung mit dem von Tortosa.[12] In Pawlowsk dagegen, wo P.G. u. beide Leitfähigkeiten registriert werden, wird ein Maximum des Stromes im August und ein Minimum in Februar beobachtet, während sich der tägliche Gang dem an andern Orten, z. B. Davos beobachteten anschliesst.

Der säkulare Gang des Stromes ist in Tortosa derselbe wie der des P.G. Dieses ist eine Bestätigung der von Benndorf gemachten Annahme, dass die mittlere Leitfähigkeit der Atmosphäre im Laufe einer Sonnenfleckenperiode konstanter bleibt als der Zustrom. Die Folgerungen, die L. A. Bauer, für die Abhängigkeit des P.G. von der Sonnentätigkeit gezogen hat, gelten

[11] A. GOCKEL, *Elster und Geitel Festschrift*, S. 143.

[12] H. MARKGRAF, *Meteor. Zt.*, 41. 65. 1924.

deshalb auch für den Strom. Bemerkenswert ist, dass in den Jahren 1916-20 der Strom in Tortosa prozentual dieselbe Abnahme zeigt wie auf den Ozeanen, nämlich etwa 15%.

5. In den Darstellungen, die sich mit der Abhängigkeit des P.G. von meteorologischen Faktoren beschäftigen, findet man die Angabe, dass das P.G. abnimmt mit zunehmender Temperatur und umgekehrt. Hier wird ein zeitlicher Zusammenhang, der allgemein nur im Jahresgang auf der nördlichen Halbkugel vorhanden ist, zu einem ursächlichen gemacht. Schon Exner, der die Veränderungen des P.G. durch Aenderungen des Dampfdrucks erklären wollte, dessen Gang ungefähr parallel dem der Temperatur ist, stiess auf die Schwierigkeit, dass im täglichen Gang das Verhältnis des P.G. zur Temperatur fast umgekehrt ist wie im jährlichen.

Dass die absoluten Werte des P.G. von der Temperatur unabhängig sind, resp. dass diese letztere höchstens eine sekundäre Rolle spielt, insofern niedere Temperaturen die Bildung von Dunst u. Nebel begünstigen, zeigt ein Vergleich der Jahresmittel an verschiedenen Stationen. In Upsala u. Karasjok (Lappland) ist z. B. das P.G. niedriger als in dem warmen Tortosa. In Kew mit ozeanischem Klima, also mildem Winter ist das P.G. in dieser Jahreszeit bedeutend höher (405 Volt/Meter) als in München 249 V/m), das kalte Winter hat u.s.w. Auch hier spielt die Leifähigkeit eine Rolle.

Institut fuer Kosmische Physik,
Universitaet Freiburg (Schweiz), April 22, 1926.

NOTES

14. *Porto Rico Magnetic Observatory.*—Referring to Note 7, the following additional details have been supplied by Col. E. Lester Jones, Director of the United States Coast and Geodetic Survey: "The instrumental equipment of the new Coast and Geodetic Survey Magnetic Observatory near San Juan, Porto Rico, was mounted in time to begin routine operation on January 1, 1926. The work of this Observatory is a continuation of that begun on the Island of Vieques, Porto Rico, in 1906, and discontinued November 30, 1924. The new site is about 8 miles south of San Juan, near the new municipal filtration plant. The comparison observations between the two sites have not yet been made, but this will be done in the near future. Modifications have been made in the designs of both *absolute instruments and variometers.* The old Cooke magnetometer has been mounted on a ten-inch horizontal circle reading to ten seconds and new lenses have been mounted in the magnets. A field earth inductor and galvanometer of the C.I.W. type is in temporary use for dip observations. The telescope of this galvanometer has been replaced by an optical system focusing a beam of light on a scale about four feet in front of the galvanometer, thus greatly increasing the optical leverage of the system. Modifications in the *magnetograph* concern primarily the elimination of temperature effect as worked out by Mr. George Hartnell, Observer-in-Charge of the Cheltenham Observatory, and changes in the lighting and recording systems. For all practical purposes temperature compensation was accomplished on the first set-up. A small flash-light lamp used in connection with Edison primary cells furnishes the source of light. On a new design of magnet-mirror frame mounted in the D and H variometers, vertical adjustments of the mirror can be made by simply turning an adjusting screw, thus eliminating the unsatisfactory method of bending the mirror frame when adjustments are necessary. Reserve spots from these two instruments are made by placing achromatic prisms in front of portions of the single plane mirrors on the magnet-mirror frames. A new weight driven clock and time-break mechanism have been mounted in the old recording box. It is expected that all magnetograms from this Observatory will be of a quality capable of direct photographic reproduction. The old *Bosch-Omori seismograph* was remounted with modifications tending to improve time control and increase the magnification of local earthquakes."

15. *Personalia.*—We regret to record that Admiral Sir *John Franklin Parry*, K.C.B., President of the Directing Committee of the International Hydrographic Bureau, Monaco, died on April 21, 1926. Prof. *G. Angenheister* has accepted a position as Abteilungsvorsteher am Preuss. Geodätischen Institut, Potsdam. At the April meeting of the American Geophysical Union the following officers for the Section of Terrestrial Magnetism and Electricity were elected for the period 1926-1929: *N. H. Heck*, chairman; *J. H. Dellinger*, vice-chairman; and *J. A. Fleming*, secretary.

16. *Commission for Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Committee.*—It is intended to hold a meeting of this Commission on or about September 17, 1926.

17. *Magnetic Storm and Aurora of June 1, 1926.*—The following brief report was received from the Director of the Coast and Geodetic Survey: "The storm began at the Cheltenham Magnetic Observatory June 1st at 6h 9m and ended June 2, at 5 h, 75th meridian time; range of D, 58.′7; range of H, 265γ; and range of Z, 362γ. Maximum D, 7° 20.′3, occurred at 3h 25m June 2, and minimum D, 6° 21.′6, at 9h 34m June 1st. Maximum H, 18949γ, occurred at 15h 45m on June 1st, and minimum H, 18684γ, at 9h 52m on June 1st. Maximum Z, 54938γ, occurred 17h 46m on June 1st, and minimum Z, 54573γ, at 2h 30m on June 2. The normal values at this Observatory are: Declination, 6° 42′ W; average H, 18823γ; and average Z, 54755γ. The storm was characterized by a sudden commencement and a sudden increase of H by 30γ. An *aurora* was first noted at 9h 18m P. M. on June 1st. It had the appearance of a light cloud circling upward. It started in the north and extended 50° toward the Zenith. This changed to parallel streamers emanating from a point in the north region and extending into the north and lasting until 9h 25m P. M. Later a peculiar shaft was noted starting about 30° W. of N., passing through the constellation of Castor and Pollux, which seemed to drift off towards the west and lasted until 9h 30m." No reports received thus far of *sunspot observations* serve to explain adequately the occurrence of this magnetic storm.

DIRECT SCALING OF ABSOLUTE MAGNETIC VALUES.

By W. N. McFarland.

The operation of a magnetic observatory has for its object the eventual tabulation of the results in some form which will be convenient for the purposes of the investigator. The successful operation of the magnetograph, however, by no means completes the labor necessary for the attainment of this end. Several routine processes have to be maintained in order that the resulting records may be controlled, including absolute observations of the magnetic elements, and the determination of scale values of the magnetogram, all of which must be done at regular intervals.

The computer's work begins after the magnetogram has been developed and dried. The adjustment of the base-line and scale-value observations, while basic for proper carrying out of the rest of the program, is not long or laborious, but the measurement of the magnetograms and the subsequent reduction to the final absolute values which are printed, while simple in method, is both laborious and monotonous on account of the large number of operations of the same character which must be completed before the final values are obtained.

It has always been the practise in the Coast and Geodetic Survey to have the measuring of the ordinates of the curves done at the observatory, after which the tabulated measurements are sent to the Washington office, where the final adjustment of scale values and base lines is made, and the computational work necessary to reduce the scalings to absolute values is done. This latter process is formidable because of the very number of figures which must be handled. For instance, the conversion of the measured intensity ordinates of the magnetogram into magnetic units involves the multiplication of each measured ordinate by a number of three figures, and a second multiplication for a check. Since hourly values are tabulated, a maximum and minimum value, and a range for each day, it can be readily computed that about 40,000 multiplications each year for each observatory are required to reduce the scaled ordinates of horizontal and vertical intensity to their corresponding values in gammas, and to provide a check for the multiplications.

The ordinates in millimeters having been reduced to ordinates in gammas, it remains to add base-line values and temperature corrections to the ordinates, the sum of all three being the final absolute value. Here again the process itself is simple, but laborious on account of the number of values which must be handled. A little computation will show that no less than 28,000 additions of

either two or three numbers of two or three figures each are required to complete this phase of the computational work, and on top of this any additional work required by the system of check. Inasmuch as the compensation of both horizontal and vertical intensity variometers for temperature, so that the resulting movements of their magnets are not affected by changes of temperature, has already passed the experimental stage, and is in the process of installation as a regular feature of observatory operation, its feasibility and its ultimate accomplishment both will be considered as established, and the necessity for taking account of temperature corrections will be considered to have been eliminated in the further discussion.

Neglecting then temperature changes, the production of absolute values of the magnetic elements from the magnetogram involves a multiplication and an addition. Obviously if instead of using a millimeter scale to measure the length of an ordinate, we should use a scale graduated so that one division was equal to the length of one gamma on the magnetogram, the resulting ordinate would be already an ordinate in gammas, and no conversion process would be needed. Also, if the same scale were set, not with zero at the base line, but with the base-line value at the base line, the addition of base-line value and ordinate would be made on the scale, and the final absolute value would be read directly on the scale. This in skeleton form is the process which has been devised to make possible the reading of the absolute values of the magnetic elements directly from the magnetograms.

The cheap and speedy production of scales has been the chief problem involved. It has been accomplished by making first a drawing of the desired scale, photographing the drawing on glass with the desired reduction, and printing on thin aluminum plates. Cutting the scales out of the plates, trimming, and varnishing produce sufficiently precise and durable scales with reasonable despatch, and at small expense. The manufacture of scales for the three elements differs somewhat among the three for several reasons, so that they may be taken in order, progressing from the simplest case.

The scale value of the declination curve is constant for a given distance and fiber, has no variation with ordinate, and moreover for convenience in reading has usually been established at about unity, so that the scale required for reading values of declination can approximate closely the ordinary milimeter scale, and can be used indefinitely unless the instrument is moved, or some other radical adjustment is made. For the construction of this scale a drawing was made three times the size of the finished scale, which was then photographed with the reduction necessary to give it the desired scale value. The negative was measured to insure that the reduction had been satisfactorily accomplished, and then prints were made on an aluminum plate about one-half a millimeter in thickness, which seems heavy enough to stand all the usage the

scale is likely to receive. The printing process is the same as that used in the Coast and Geodetic Survey for the production of the aluminum plates from which its charts are printed. It gives black lines on the light grayish surface of the grained aluminum, which while not so good as black on white, nevertheless is quite easy to read. Printing on xylonite and paper was tried also, but it was found that shrinkage of these materials in the developing and fixing baths was so considerable and variable that the resulting scales could not be relied upon. The grained aluminum surface takes finger prints and all sorts of stains very easily; also the photographed lines of the scales are easily obliterated by handling, so that after the scales have been cut out of the plate and trimmed to the desired dimensions the grained surface is given a coating of clear varnish, and baked, which protects it against any ordinary usage.

The scale value of the horizontal intensity curve is not constant, but has a variation with ordinate, and consequently its formula contains a term which is dependent upon the position of the curve on the magnetogram. For instance the formula which expresses the scale value of the horizontal intensity curve at the Cheltenham Observatory is now and has been for about two years

$$s=2.81+.003\ h$$

In general form this is

$$s=a+bh$$

where s is the scale value at the distance h in millimeters from the base line, that is, the number of gammas in one millimeter. Regarding the scale value as the rate of increase of the ordinate in gammas with reference to the ordinate in millimeters, then

$$s=\frac{d\gamma}{dh}$$

$$\frac{d\gamma}{dh}=a+bh$$

$$\gamma=ah+\frac{bh^2}{2}$$

$$h=\frac{-a+(a^2+2b\gamma)^{1/2}}{b}$$

This last formula gives the number of millimeters from the base line (h) of any desired number of gammas of a scale (γ), and can be used to compute the positions of the graduations of a scale which will give directly the ordinates of the curve in gammas.

It would be laborious and unnecessary to compute the position of each individual graduation of this scale. However, a few of them must be computed and plotted on the drawing, after which the intervening graduations can be put in at equal distances apart. At this point it is desirable to know how close together the computed graduations should be in order that no appreciable error shall be introduced into the positions of the equally spaced intervening graduations. The formula for this computation is stated below

without derivation, as it will be useful to any one who wishes to construct such a scale

$$(d\gamma)^2 = -\frac{8e}{b}(a^2+2b\gamma_1)^{3/2}.$$

in which $d\gamma$ is the interval between the computed graduations, e is the maximum allowable error in the position of the interpolated values, a and b are the quantities in the scale value formula, and γ_1 is the ordinate in gammas of the lower end of the scale where the changes are most rapid.

The computer will know that the interval between computed graduations cannot be greater than the computed value of $d\gamma$ and can choose for his interval some lesser number, which will be represented on the scale by graduations, and compute a series of positions at this chosen interval from the formula for h. The computational work having been completed, the drawing can be made by plotting the computed positions and filling in the intervening graduations at equal intervals with proportional dividers or some other means of equal spacing. The drawing may well be made about three times the size of the finished scale in order to allow imperfections in workmanship and plotting to reduce themselves in the photographic reduction. The procedure of photographing, printing, trimming and varnishing will be that already described for the declination scales.

The production of the vertical intensity scales offered a special problem on account of the drift and continual change to which the scale value is subject. This makes it necessary to have some provision by which scales of varying value can be supplied. To begin with, it was considered satisfactory to have scales for values at intervals of about one per cent of the scale value. Thus if the scale value was about 4.00, scales were constructed for 4.00, 4.04, 4.08, etc., and the jump from one scale value to the other would be made at the half way point. These scale values were also used in the base-line computations. This is also an approximation, but an examination of the process will show that the two approximations balance each other to such an extent that the error introduced by their use is of smaller order than others which are inherent in the observations themselves.

Inasmuch as the formula expressing vertical-intensity ordinates in gammas is linear, like the declination ordinates, photographic reduction can be used to bring a single drawing down to any desired size. The first step then was to construct a master diagram, containing a series of scales so spaced that they differed successively by the one per cent of the scale value which had been considered would be satisfactory. While one diagram of this kind would be sufficient for each observatory, the necessity of figuring the scales differently for each observatory made it desirable to provide a master diagram for each observatory, and to get this the original drawing was photographed and paper prints made. These prints

were then figured as required for each observatory. Photographing the prints with the desired reduction, printing, trimming, and varnishing as in the previous cases completed the process. Each photograph will produce as many scales as were in the original master diagram.

From this preliminary work there resulted a series of scales about 20 centimeters long, which is the width of the widest type of magnetogram, and 2.5 centimeters wide. To use them requires some type of holding apparatus for both scales and magnetograms, and a method of averaging the ordinates for the period of an hour. For this purpose there were provided a reading board, three T-squares, one for the scale of each element, and a piece of plate glass suitably squared and etched. The reading board is made somewhat larger than the magnetogram and inclined at a slight angle to the horizontal as this seemed more convenient for use than a level board. It is supplied with a clamp to hold the magnetogram in place by friction. The upper edge of the board is made a straight edge so that a T-square can be slid along it and the edge of the square will always remain perpendicular to the edge of the board. The scale is clamped to the T-square with the graduations running along the right edge of the ferrule. Consequently the scale is maintained perpendicular to the edge of the board and can be moved to any part of it. A rectangular piece of plate glass with lines etched on the under side is provided to average up the hourly values. This glass is similar in principle to that which has been used heretofore for this purpose, but it has received some necessary modification to adapt it. Vertical lines are two centimeters apart, which is the width of the hour spaces in the Eschenhagen magnetograph. The horizontal line is the integrating or averaging line. On the upper surface of the reading glass, which is level with the surface of the scale, and directly over the ends of the integrating line is etched a short line two or three millimeters long which abuts against the graduations of the scale, and serves as an index by means of which the scale may be read. [See Fig. 1.]

Before scaling is started the scale value of Z and the base-line values of D, H, and Z must have been determined in their final form if the scalings are to be final. This ordinarily requires that the results of scale value and absolute observations for at least one month subsequent be at hand, in order that their drift if any may be adequately determined and taken into account. A T-square is required for each of the three scales. To start scaling one of the scales is clamped on its T-square, which is put into place on the board, and over one end of the magnetogram. The magnetogram is then slid in its clamp until the base line comes directly under its value on the scale. Both ends of the magnetogram having been set in this way, the curve is always under its absolute value on the scale. The reading glass provides the average hourly position and its index gives the reading of the scale. When the reading of one element has been finished, another T-square with its scale is laid

down on the board, and without moving the magnetogram at all from its previously established position, the scale is slid in its clamp until the base line of the element being considered is directly under its value on the scale. The trace of this second element is then at any point under its absolute value on the scale, and the scalings can be made as for the first element. Treat the third element in the same manner. When a second magnetogram is placed on the board, it will have to be set to fit one of the scales, and will then be in position for both the others, as the distances between base lines on the magnetograms may be taken to be a constant unless one of the variometers is disturbed.

The above method of reading hourly ordinates is now in use at the Cheltenham Observatory and the readings are made with practically the same facility and accuracy as with the glass scales formerly used for reading in millimeters. A comparison of the two methods was made in the case of horizontal intensity for the month of October, 1925, and it was found that 50 per cent of the hourly values agreed exactly, 42 per cent differed by one gamma and 8 per cent by two gammas or more. The greatest difference was three gammas and this occurred only three times. This is a very satisfactory agreement. Where only whole gammas are tabulated, differences of one gamma are bound to occur frequently and occasional differences of two are to be expected. There is also the uncertainty of estimating the average ordinate for an hour, particularly when the curve is very irregular, which is involved in either method of reading.

The aim has been of course to reduce the amount of time and tedious labor which must be spent on the compilation of the observatory statistics. What has been accomplished is the elimination of the steps of conversion to magnetic units, and addition of the base-line value. As far as the intensity elements are concerned, the complete application of the method depends on the compensation of the temperature effect in the variometers; but even where this has not been done, it is felt that the scaling in magnetic units and in final values with exception of the temperature correction will be a distinct gain. The method of direct scaling eliminates so many operations that it is thought to present a possible solution of a problem which has been of much concern to those interested in the advancement of studies in terrestrial magnetism—the inability of many stations to publish hourly values, or in some cases to publish any values at all.

United States Coast and Geodetic Survey,
Washington, D. C.

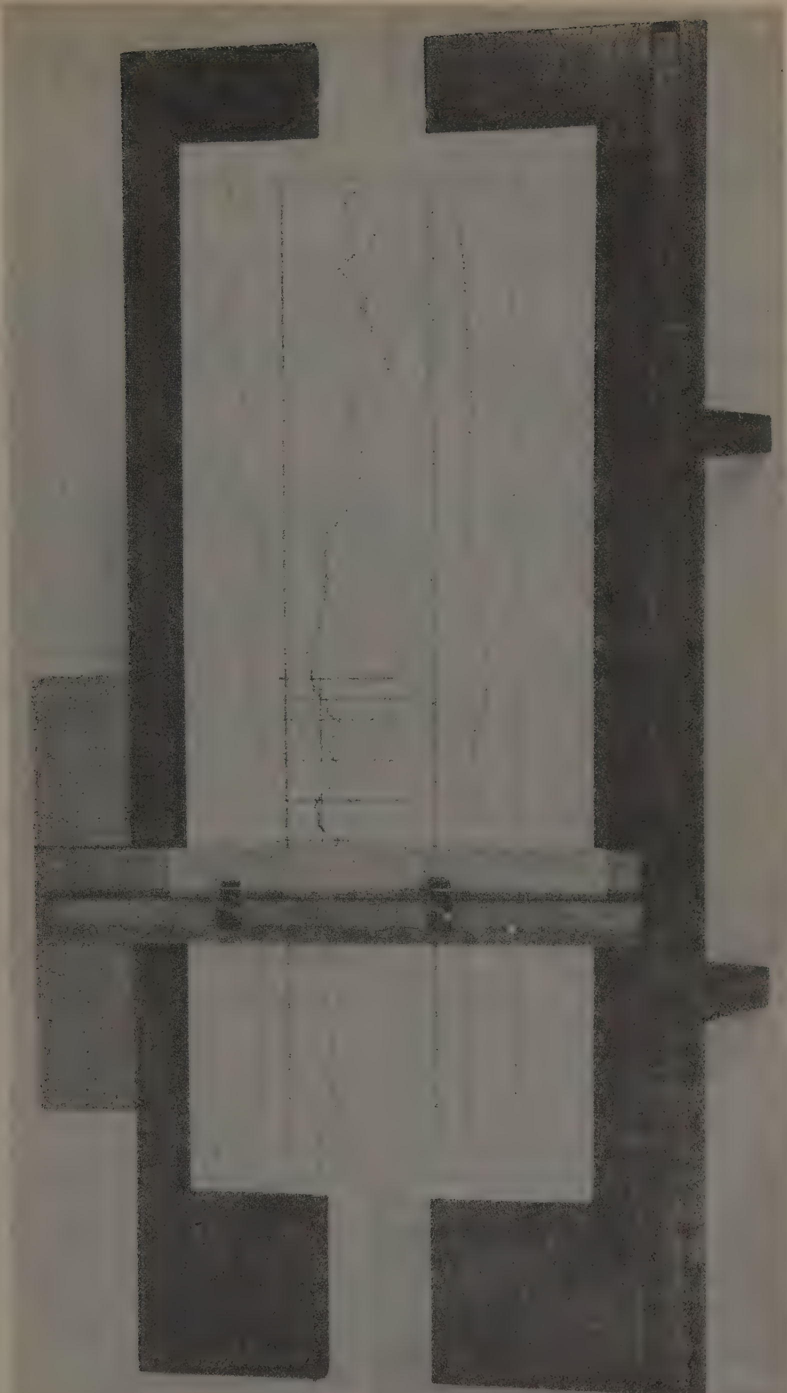

Fig. 1.—Reading Board

LIST OF RECENT PUBLICATIONS

A. Terrestrial and Cosmical Magnetism.

ANTIPOLO OBSERVATORY. Hourly results of the observations made at the Magnetic Observatory of Antipolo near Manila, P. I., during the calendar year 1922. (Part IV of the annual report of the Weather Bureau for the year 1922.) Manila, Bureau of Printing, 1925, 47 pp. 29 cm.

BALDET, F., V. BURSON ET H. GRENAT. Sur la perturbation magnétique et l' aurore boréale du 14 avril 1926. Paris, C.-R. Acad. sci., T. 182, No. 16, 1926 (962-963).

BANGKOK. Report on the operations of the Royal Survey Department, Ministry of War, for the year 1923-1924. Bangkok, Bangkok Times Press, Ltd., 1925 (61 with pls. and maps). 34 cm. [Pp. 34-35 contain a brief statement regarding the magnetic survey work and the magnetic stations occupied are shown on one of the maps.]

BATAVIA. Observations made at the Royal Magnetic and Meteorological Observatory at Batavia, v. 44, 1921. Published by order of the government of Netherlands East-India, by Dr. C. Braak, Director. Batavia, 1923 (xix+104 with 3 plates of curves). 36 cm. [Contains magnetic observations made in 1921.]

BAUER, LOUIS A. Concerning proposal of concomitant solar and magnetic observations. Abstr. Pop. Astr., Northfield, Minn., v. 34, No. 3, Mar., 1926 (183).

BERLIN, PREUSSISCHES METEOROLOGISCHES INSTITUT. Bericht über die Tätigkeit des Preussischen Meteorologischen Instituts im Jahre 1925. Mit einem Anhang enthaltend wissenschaftliche Mitteilungen. (H. v. Ficker, Direktor.) Berlin, Veröff. met. Inst., Nr. 335, 1926, 111 pp. 24 cm. [Brief account of Magnetic Work, pp. 28-31]

CHEVALLIER, R. Sur l' uniformité d' aimantation des terres cuites. J. Physique et le Radium, Paris, Sér. 6, T. 7, No. 3, 1926 (92-96).

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Perturbation magnétique du 5 mars 1926 et perturbations des premiers mois de l' année. Paris, C.-R. Acad. sci., T. 182, No. 12, 1926 (733-735).

FISCHER, N. Die wirtschaftlichen Schäden der tropischen Wirbelstürme. Hamburg, Aus d. Arch. Seewarte, Jahrg. 43, Nr. 1, 1925 (54 mit 1 Karte). 28 cm.

GROSSARD, LT.-COL. Mission de délimitation de l' Afrique Equatoriale Française et du Soudan Anglo-Égyptien. Paris, Librairie Émile Larose, 1925 (viii+343 avec 2 cartes.). 25 cm. [Contains results of magnetic observations made by the Expedition.]

HAALCK, H. Anwendung der magnetischen Aufschlussmethode. Zs. Geophysik, Braunschweig, Jahrg. 2, Heft 2/3, 1926 (49-62).

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 31 SEPTEMBER, 1926 No. 3

STUDIES CONCERNING THE RELATION BETWEEN THE ACTIVITY OF THE SUN AND OF THE EARTH'S MAGNETISM.—NO.III.[1]

BY LOUIS A. BAUER AND C. R. DUVALL.

Abstract.—The *annual variation of magnetic activity* is investigated with the aid of various measures, chief of which is a quantity, F, giving the number of days per month of magnetically-disturbed days from 1906 to 1924. The average number of such days per month, F_i, during the sunspot minimum years was 4.4, and during the years of sunspot maximum, F_x was about 10; hence, F_x was only 2.3 F_i. During a solar cycle there may be, on the average, about 7 magnetically-disturbed days per month.

For the period 1906-1924, F showed maxima values (about 9.2 days) in the equinoctial months and minima values (about 5.8 days) in the solstitial months; the ratio $9.2/5.8 = 1.6$. The marked change in F from month to month cannot be successfully correlated with varying sunspottedness during the year. The correlation coefficient between the F-measures and the cosine of the Sun's declination is $+0.95$, and that between F and the cosine of the Earth's heliographic latitude is -0.82; in the first case we have a direct (+) correlation, and in the second an inverse (−) correlation.

ANNUAL VARIATION OF MAGNETIC ACTIVITY.

1. Section 21 of No. I of these "Studies" (*Terr. Mag.*, vol. 30, p. 206) dealt briefly with the difficulty of "attempting any comparison, month to month, or day to day, between measures of solar activity and geophysical activity," because of the effects which enter primarily into the geophysical measures during the Earth's annual motion around the Sun. Thus in terrestrial magnetism it has been known for some time that, on the average for a number of years, in the Northern and Southern Hemispheres, both the frequency and magnitude of disturbances show maxima values near the equinoctial months and minima values near the solstitial months. The same phenomenon is exhibited by earth-currents, atmospheric electricity, and polar lights,[2] but not usually by any measure of solar activity, except near the years of minima.[3] The year 1920 doubtless accidentally showed some tendency to a double periodicity in the Wolfer sunspot numbers, chiefly owing to the high value in March;[4] it was owing to this fact that the correlation coefficient between various measures of magnetic

[1] The first of these "Studies" (I) appeared in *Terr. Mag.*, vol, 30 (1925), pp. 191-213, and the second (II) in vol. 31, (1926), pp. 37-47.

[2] BAUER, L. A., *Terr. Mag.*, vol. 27 (1922), p. 24; also vol. 29 (1924), p. 179.

[3] BAUER, L. A., *Terr. Mag.*, vol. 26 (1921), pp. 113-115.

[4] *Terr. Mag.*, vol. 30 (1925), p. 86.

activity and of solar activity was found to be higher in 1920 than in 1915 ("Studies" I, *Terr. Mag.*, vol. 30, Table 13, p. 207).

2. The annual variation, or periodicity, of magnetic activity has been investigated with the aid of a variety of magnetic measures and for various series and periods of observation. One of the most instructive of these measures is what we shall designate as the *F*-measure; it is the frequency, or number, of magnetically-disturbed days per month, namely, the days whose "magnetic character" $\gtreqless 1$. A day characterized by magnetic observatories as 1 is a day of moderate disturbance; the number 2 (the highest grade at present generally assigned) denotes a greatly disturbed day; the lowest grade 0 denotes a day apparently undisturbed. To obtain *F* use has been made of the mean magnetic character numbers, derived from some forty observatories and published by the Commission for Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Committee; annual summaries beginning with 1906 have appeared regularly in the journal *Terrestrial Magnetism.*[5]

3. Table 1 contains the values of *F* obtained by dividing the total number of days of magnetic character $\gtreqless 1$ during the year by 12, and similarly the Wolf-Wolfer sunspot numbers, S'_n, corresponding to the selected days were derived. Figure 1 gives a graphical representation of the quantities in this table. It will be observed that while there is a general correspondence between the two curves, especially since 1910, the *F*-curve (No. 2) shows a number of features not shown by the sunspot curve (No. 1). The correlation coefficient, r, for the entire period, 1906-1924, is 0.67 ± 0.09.

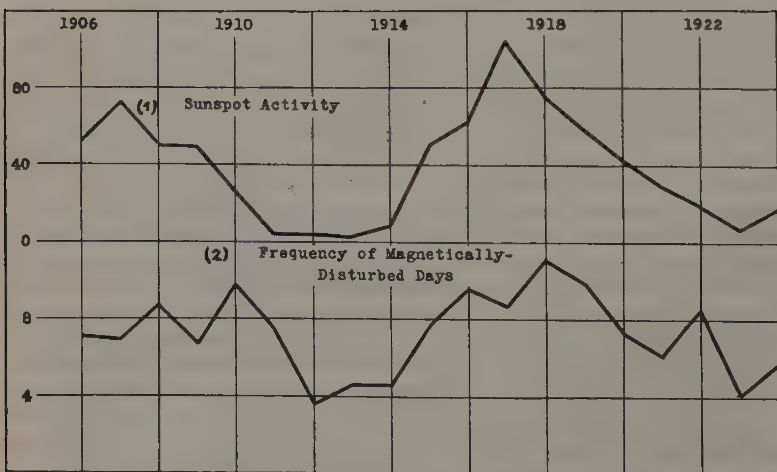

Fig. 1.—Sunspot Activity and Frequency of Magnetically-Disturbed Days, 1906-1924.

[5] See, for example, the summary for 1924 in *Terr. Mag.*, vol. 30 (1925), p. 116.

TABLE 1.—*Frequency, F, or number of magnetically-disturbed days per month (magnetic character $\geqq 1$), and corresponding sunspot numbers, S'_n.*

Year	F	S'_n	Year	F	S'_n	Year	F	S'_n	Year	F	S'_n
1906	7.0	52.5	1911	7.4	3.8	1916	9.5	61.1	1921	6.2	28.7
1907	6.9	**73.0**	1912	*3.6*	3.7	1917	8.7	**104.2**	1922	8.5	18.9
1908	8.7	49.4	1913	4.6	*2.2*	1918	**11.1**	74.8	1923	*4.1*	*6.9*
1909	6.7	49.7	1914	4.6	8.7	1919	9.9	58.1	1924	5.9	16.7
1910	**9.8**	25.4	1915	7.7	51.2	1920	7.2	41.5			

4. Of special interest is the fact observed from Table 1 that even during the years of minimum sunspot activity (1913 and 1923) there were on the average 4.4 magnetically-disturbed days per month, or nearly half as many (about 10) as during an average sunspot maximum year. Thus we see once again that a solar measure depending on sunspottedness alone does not give us a true index of expected magnetic activity. On the average during the whole period, 1906-1904, there were 7.3 magnetically-disturbed days per month.

5. Table 2 contains the average monthly values of F and the corresponding average sunspot numbers, S'_n, for days of magnetic character $\geqq 1$, and finally the values of the function, $k = (\cos \delta)/\rho^2$, in which δ is the Sun's declination and ρ, the radius vector or distance between the Earth and Sun. The three sets of quantities are shown graphically in Figure 2. It will be seen that the F-quantities distinctly show maxima in the equinoctial months, March and September, and minima values in the solstitial months, June and December. The variation in F during the year (9.8 in March and 5.5 in June) is almost comparable with the variation during a sunspot cycle (see Table 1).

TABLE 2.—*Average monthly values for 1906-1924.*

Month	F	S'_n	k	Month	F	S'_n	k	Month	F	S'_n	k
Jan.	6.2	33.7	0.97	May	6.9	39.4	0.93	Sep.	**8.6**	40.5	**0.99**
Feb.	7.6	38.4	1.00	Jun.	*5.5*	39.2	*0.89*	Oct.	8.4	34.9	1.00
Mar.	**9.8**	42.1	**1.01**	Jul.	6.2	41.0	0.90	Nov.	6.7	35.6	0.97
Apr.	7.7	31.4	0.98	Aug.	7.3	38.2	0.95	Dec.	*6.1*	37.2	*0.95*

6. The mean value of F during the six-month period (A, April to September), when the Earth is farthest from the Sun, is 7.03, and for the six-month period (P, October to March), when the Earth is nearest the Sun, is 7.47; hence, $F_P/F_A = 7.47/7.03 = 1.06$. There is thus an indication that F, besides being subject to a pronounced semi-annual periodicity, may also be subject to a small annual one. We obtain from the Fourier analysis:

$$F = 7.25 + 0.21 \sin(\theta + 62°) + 1.65 \sin(2\,\theta + 287°) + \ldots \quad (1)$$

θ is counted from midnight of December 31 at the rate of 15° per half month of uniform length. The amplitude of the six-month

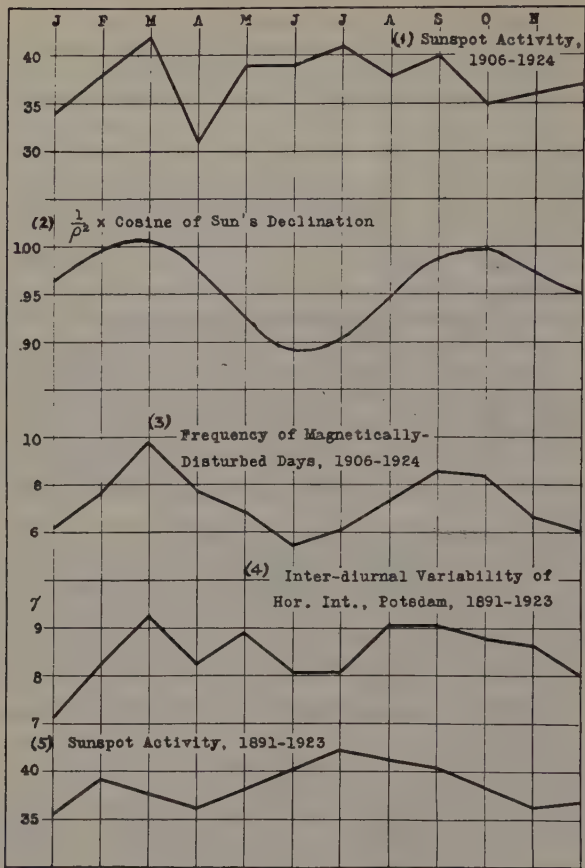

Fig. 2.—Annual Variation of Magnetic Activity.

term is 7.8 times that of the 12-month term. The maximum value of the annual term, according to the analysis, occurred on January 29, and the maxima of the semi-annual term occurred on March 24 and September 23, hence, practically at the equinoctial dates.

7. A comparison of Curves 1 and 3 of Figure 2 immediately shows that the correlation, month to month, between sunspot activity and frequency of magnetically-disturbed days, is small; in fact, r is found to be only $+0.18$. On the other hand, the correlation between Curves 2 and 3 is manifestly high; r for the F- and k-quantities turns out to be $+0.82 \pm 0.06$. The function k enters into the expression for the variation of the intensity of solar radiation during the year for a point on the equatcr.[6]

If we omit the factor $1/\rho^2$, then the correlation coefficient, r, for the quantities, F and $\cos \delta$ is found to be $+0.95 \pm 0.02$.

[6] HANN'S *Meteorologie*, 1915, p. 784

8. The opinion has been expressed that the annual variation of magnetic activity may have to be referred to the varying heliographic latitude, ϕ_s, of the Earth during the year. The Earth in its revolution around the Sun passes through the plane of the Sun's equator about December 6 and June 4 or 5, hence, about the times of *minimum* magnetic activity. At the times of maximum activity, March and September, ϕ_s is respectively $-7^\circ.1$ and $+7^\circ.1$. Accordingly, if a relationship be assumed between F and ϕ_s of the general character, $F=k' \cos \phi_s$, where k' is some constant to be determined by least squares, we obtain for the correlation coefficient -0.82 ± 0.06. In other words, magnetic activity in this case would apparently vary during the year *inversely* as the cosine of the heliographic latitude of the Earth.

9. Table 3 contains the mean monthly values, 10 u, of Schmidt-Bartels' quantitative measure of magnetic activity for the 33-year period, 1891 to 1923, and dependent on the inter-diurnal variability of the horizontal intensity, H, as derived alone from the Potsdam records, the measures having been reduced to the magnetic equator by Bartels.[7] We have preferred to use the Potsdam data alone so as to make the entire series as homogeneous as possible. The mean monthly sunspot numbers for the same period are also entered in the Table.

TABLE 3.—*Mean monthly values of 10u and of sunspot numbers, S_n, 1891-1923.*

Month	10 u	S_n	Month	10 u	S_n	Month	10 u	S_n	Month	10 u	S_n
	γ			γ			γ			γ	
Jan.	*7.10*	35.5	Apr.	8.24	36.2	Jul.	*8.08*	42.2	Oct.	8.78	38.5
Feb.	8.25	39.1	May	8.96	38.1	Aug.	**9.06**	41.2	Nov.	8.65	36.4
Mar.	**9.28**	37.9	Jun.	*8.08*	40.2	Sep.	**9.06**	40.4	Dec.	8.02	36.9

It will be seen that the u-measures (Curve 4, Fig. 2), while not as regular as the F-measures (Curve 3, Fig. 2), nevertheless also show a pronounced double periodicity during the year, the maxima and minima occurring near the equinoctial and solstitial months, respectively. The third maximum, shown by the May quantity, is chiefly due to the very large magnetic disturbance which occurred May 13-17, 1921; for that month u has the largest value in Bartels' entire table. A comparison of Curves 4 and 5 again shows that the correlation between the annual variations of magnetic activity and of sunspot activity is very small.

Chief assistance in the computational work was received from Mr. C. C. Ennis, who also constructed the graphs for Figures 1 and 2.

[7] BARTELS, J: Erdmagnetische Aktivität 1836-1923, *Veröff. Preuss. Met. Inst.*, Nr. 332, Archiv des Erdmagnetismus, Heft 5, pp. 47-50.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON.

THE MAGNETIC CHARACTER OF THE YEAR 1925.

The annual review of the "Caractère magnétique de chaque jour" for 1925 has been drawn up in the same manner as for the preceding year.[1] Forty-two observatories contributed to the quarterly reviews, 39 of which sent complete data. Table II of the annual review, containing the mean character of each day and each month, the lists of "calm days" and "most disturbed days," and the days recommended for reproduction is reprinted here.

G. VAN DIJK.

DATES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	MEAN
JAN.	0.1	0.1	0.5	0.0	0.7	0.0	0.2	0.1	0.2	0.0	0.0	0.1	1.0	0.1	0.1	1.5	1.4	1.0	1.8	1.3	0.9	0.2	1.1	0.9	0.0	0.1	0.1	0.0	0.1	0.3	0.0	0.44
FEB.	0.7	0.1	0.0	0.0	0.1	0.3	0.5	1.0	1.5	0.3	0.2	0.6	0.5	0.4	0.1	0.6	0.7	0.3	0.7	0.7	0.0	0.0	0.0	0.7	0.8	0.1	0.0	0.8				0.42
MAR.	0.9	0.1	0.1	0.4	0.9	0.4	0.1	0.1	1.5	1.0	0.4	0.2	0.1	0.1	1.4	0.4	0.2	0.0	0.3	0.8	0.2	0.3	0.6	0.5	0.1	0.5	0.9	0.0	0.5	0.1	0.1	0.42
APR.	0.7	0.8	1.1	0.1	0.9	0.7	0.7	0.6	1.0	1.1	0.8	0.9	0.1	0.1	1.0	0.6	0.1	0.1	0.0	1.1	0.3	0.2	0.2	0.1	0.0	0.4	0.7	0.3	0.5	0.2		0.52
MAY	0.1	0.0	0.4	1.8	1.0	0.3	0.4	0.6	0.8	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.8	0.8	0.1	0.1	0.4	0.2	0.5	0.4	0.5	0.8	1.3	0.5	1.4	1.3	0.47
JUN.	0.9	0.9	1.0	0.8	0.5	1.0	0.3	0.2	0.1	0.3	0.5	0.3	1.9	0.8	0.5	0.9	0.9	0.6	0.2	0.0	0.0	0.3	1.3	1.9	1.3	0.5	1.2	1.3	0.8	0.8		0.74
JUL.	0.7	0.5	0.4	0.2	0.5	0.3	0.1	0.2	0.9	1.0	0.6	0.1	0.1	0.7	1.3	0.1	0.0	0.1	0.4	0.1	0.9	1.0	0.7	0.4	0.9	1.7	1.4	1.1	0.4	0.0	0.1	0.55
AUG.	0.5	0.2	1.0	0.9	0.3	0.6	1.3	1.3	0.9	0.6	0.1	0.0	0.0	0.3	0.1	0.3	0.8	1.1	0.8	0.3	0.3	1.5	1.8	0.6	0.7	0.5	0.1	0.0	0.4	0.9	0.6	0.61
SEP.	1.6	1.6	1.0	0.8	0.7	0.5	1.1	0.2	0.5	0.0	0.0	0.0	0.1	1.7	1.8	1.1	0.9	0.5	0.2	0.2	1.9	1.1	0.8	1.8	0.6	0.5	0.1	0.1	0.0	0.0		0.71
OCT.	0.8	0.3	0.1	1.1	0.9	0.7	0.4	1.2	1.6	1.0	1.1	1.5	0.9	0.7	0.9	0.7	0.4	0.0	0.3	0.8	1.7	1.5	1.9	1.8	0.7	0.4	0.9	0.2	0.0	0.0	0.9	0.82
NOV.	1.3	1.1	0.2	0.1	0.0	0.2	0.2	1.1	1.7	1.5	1.1	0.4	0.9	1.4	0.7	0.1	0.1	0.1	0.1	0.3	0.0	0.1	0.2	0.9	0.5	0.1	0.0	0.0	0.0	0.0		0.48
DEC.	0.5	0.4	0.1	0.4	0.9	1.4	0.9	0.4	0.5	0.6	0.5	0.2	0.5	0.1	0.9	0.6	0.0	1.0	0.3	0.7	0.0	0.1	0.6	0.8	0.4	0.0	1.5	1.7	0.5	0.6	0.5	0.57

	CALM DAYS						MOST DISTURBED DAYS				
JANUARY	(0.01)	4,	10,	11,	25,	28,	**16** (1.5),	**17** (1.4),	**19** (1.8),	**20** (1.3),	**23** (1.1).
FEBRUARY	(0.02)	3,	4,	21,	22,	23,	**8** (1.0),	**9** (1.5),	**24** (0.7),	**25** (0.8),	**28** (0.8).
MARCH	(0.06)	3,	8,	18,	28,	31,	**1** (0.9),	**5** (0.9),	**9** (1.5),	**10** (1.0),	**15** (1.4).
APRIL	(0.05)	4,	17,	19,	24,	25,	**3** (1.1),	**9** (1.0),	**10** (1.1),	**15** (1.0),	**20** (1.1).
MAY	(0.00)	2,	12,	14,	15,	16,	**4** (1.8),	**5** (1.0),	**28** (1.3),	**30** (1.4),	**31** (1.3).
JUNE	(0.12)	8,	9,	19,	20,	21,	**13** (1.9),	**23** (1.3),	**24** (1.9),	**25** (1.3),	**28** (1.3).
JULY	(0.05)	13,	16,	17,	18,	20,	**15** (1.3),	**22** (1.0),	**26** (1.7),	**27** (1.4),	**28** (1.1).
AUGUST	(0.03)	11,	12,	13,	15,	28,	**7** (1.3),	**8** (1.3),	**18** (1.1),	**22** (1.5),	**23** (1.8).
SEPTEMBER	(0.01)	10,	11,	12,	29,	30,	**1** (1.6),	**14** (1.7),	**15** (1.8),	**21** (1.9),	**24** (1.8).
OCTOBER	(0.09)	2,	3,	18,	29,	30,	**9** (1.6),	**12** (1.5),	**21** (1.7),	**23** (1.9),	**24** (1.8).
NOVEMBER	(0.02)	5,	21,	22,	27,	28,	**1** (1.3),	**2** (1.1),	**9** (1.7),	**10** (1.5),	**14** (1.4).
DECEMBER	(0.04)	3,	14,	17,	21,	26,	**6** (1.4),	**7** (0.9),	**18** (1.0),	**27** (1.5),	**28** (1.7).

DAYS RECOMMENDED FOR REPRODUCTION

**September 21; *May 4, June 24, August 22, September 1 and 14, October 21 and 23, and November 9.

[1]*Terr. Mag.*, vol 30 (1925), p. 116.

MICROMAGNETIC OSCILLATIONS AS OBSERVED AT THE MAGNETICAL SECTION OF THE OBSERVATORY OF IRKUTSK (ZOUY), 1925.

By Arnold Pödder.

Sensitive magnetographs reveal frequently on disturbed, as on quite calm, days waves of a peculiar type, which are characterized by their small period and which are not perceptibly connected with the Sun's activity. Some days they are very weak, but on other days their amplitudes reach very considerable values.

From the data of the special records of the Eschenhagen magnetograph at Zouy it can be concluded that two very different types of these waves exist:

> Type I.—Very regular periodical vibrations of the magnet continuing over many hours or even days; the periods are well defined and vary in the limits of from 5 to 14 seconds approximately;
>
> Type II.—Comparatively irregular vibrations having, however, a pronounced periodical character with considerably longer periods of a mean value of 34 seconds.

The genesis of both types is not yet clear. This question is not discussed here; the purpose is to examine and to present the results of special observations which I made at Zouy by means of a sensitive Eschenhagen variometer, as somewhat modified by me, and also the results of the registration of the variations of the intensity of the current induced in a wire connected with a very sensitive galvanometer.

The observations were made from January 7, 1925, to January 7, 1926. Owing to the small moment of the magnet, to the great sensitiveness of the photographic paper, and to the rapid rotation of the drum on which the paper is placed, I was able to record these vibrations almost accurately and evaluate them exactly. The paper on the drum was changed twice a day because of the great velocity of its rotation. At the beginning I was able to discover the vibrations on the records of horizontal intensity and declination only. On the records of the Lloyd balance micromagnetic oscillations of the vertical intensity were not perceptible, owing to the low sensitiveness of this instrument. Accordingly, I made some modifications in this apparatus. The usual mirrors were replaced by lighter plates of quartz, which were polished and covered with a layer of platinum, and the weight of the magnet was considerably reduced. All this increased the sensitiveness of the apparatus to 1.3γ for 1 mm. at a distance of 2,010 mm. of the apparatus from the registering part. At the same time I undertook a registration of variations of the intensity of the current in a wire connected with a galvanometer. The oscillations of its needle indicated currents which are induced by variations of the vertical intensity.

The oscillations of a very small period may be a result of the self-induction of the cable, which is a resonator emitting electromagnetic waves. The calculations made by Ebert confirmed this

completely, but the periods of oscillation are quantities of quite another order of magnitude.

Following I shall give briefly the results which I obtained in studying this interesting phenomenon from the records of the magnetic observatory in Zouy. In this work the following phases of the subject are treated:

I.—The periods and the amplitudes of the micromagnetic oscillations;
II.—The relative frequency of the different periods of oscillations;
III.—Diurnal and annual variations of the micromagnetic oscillations;
IV.—Some peculiarities of the micromagnetic oscillations and their similarity with the microseisms.

I. PERIODS AND AMPLITUDES OF THE MICROMAGNETIC OSCILLATIONS.

All magnetograms were carefully examined and the period T_p and the amplitude A of the micromagnetic waves were determined (expressed in γ[1]). The magnitude of the amplitude of the micromagnetic oscillations is deduced from the amplitude on the photographic paper as follows:

The equation of motion of the magnet having a moment of inertia K, a coefficient of damping ϵ, and a magnetic moment M, in absence of exterior field, is

$$\frac{\delta^2\phi}{\delta t^2} + 2\epsilon\frac{\delta\phi}{\delta t} + \frac{M(H+\delta H)}{K} = 0 \tag{1}$$

ϕ is the angle of deviation; H, the normal magnetic intensity; and δH, the variation relating to the time of observations.

If, too, an exterior periodical force $h_0 e^{i\omega t}$ is acting on the magnet (h_0, the amplitude of the periodically changing force, and $\omega = \frac{2\pi}{T}$, the frequency of the oscillation of this force, the equation (1) will take the form

$$\frac{\delta^2\phi}{\delta t^2} + 2\epsilon\frac{\delta\phi}{\delta t} + \omega_0^2\phi = \frac{M}{K}h_0 e^{i\omega t} \tag{2}$$

here $\omega_0^2 = \frac{M(H+\delta H)}{K}$ and ω_0 is the frequency of the proper oscillation of the magnet. For integrating we take, as usually, $\phi = \phi_0 e^{i\omega t}$; by substituting we obtain

$$(-\omega^2+2\epsilon i\omega+\omega_0^2)\ \phi_0 = \frac{Mh_0}{K} \tag{3}$$

The amplitude on the record is bound with ϕ_0 by the correlation

$$y_0 = \phi_0 d,$$

here d is the distance of the mirror to the light point on the drum.

Determining the module of the complex expression in (3), we have

$$h_0 = \frac{y_0}{d}\frac{K}{M}\sqrt{(-\omega^2+\omega_0^2)^2+4\epsilon^2\omega^2} \tag{4}$$

For simplifying the calculation we denote, as it is usual in seismology,

[1] $1\gamma = 0.00001$ C. G. S. unit.

$$\frac{\omega_0}{\omega} = \frac{T}{T_0} = u, \text{ and } \epsilon^2 = (1 - \mu^2)\,\omega_0^2$$

By substituting this in (4), we have

$$h_0 = \frac{y_0}{d}\frac{K}{M}\omega_0^2\frac{u^2+1}{u^2}\sqrt{1 - \frac{4\,\mu^2\,u^2}{(u^2+1)^2}} \qquad (5)$$

For calculating h_0 the "Seismometrical Tables" of B. Galitzin are used, in which the value of log $(u^2+1)\sqrt{1-\frac{4\mu^2u^2}{(u^2+1)^2}}$ is given for all magnitudes of u and μ happening in practice. The results of these calculations are quoted in Table 1.

The first column contains the magnitude of the period of these micromagnetic oscillations T_p, the second the amplitude A_H for horizontal force, and the third A_Z for vertical force.

TABLE 1.

T_p	A_H	A_Z
s	γ	γ
4.84	0.57	0.47
6.02	1.18	1.12
8.27	1.47	1.43
12.36	2.36	2.13
14.61	2.37	2.49

Table 1 indicates clearly that with the increase of the period of the oscillations the intensity of the micromagnetic oscillations is also increased. Such a relation we note also for the microseisms with the period T_p from 1 second to 10 seconds.[2] Only for the period 14.61 seconds a digression of this law is observed, but as the corresponding data represent only the average of 11 separate definitions (there were only three magnetograms with $T_p = 14.61$ sec.) this digression is to be attributed to casual reasons.

Now we shall turn to the *micromagnetic oscillations of type II*. As it was mentioned, these oscillations are distinguished by longer periods and by much less regular aspect. Some more regular places of such magnetograms were examined. In Table 2 the results of these computations are given. The last column contains G, the weight of the result or the number of occurrences for which the data in the table represent the average.

TABLE 2.

T_p	A_H	A_Z	G
s	γ	γ	
32.73	1.37	1.21	44
37.65	1.22	1.20	17
41.90	1.67	1.53	19
44.27	1.18	1.15	9

[2] B. GALITZIN (GOLICYN). Microseismic movements. *Acad. d. Sc. de Russie. C. R. de la Commission seism. perm.;* v. 7, livr, II, pp. 97-184. 1919.
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Here the tendency seen in the micromagnetic oscillations of type 1, namely, that, with the increasing of the period T_p the amplitude of the corresponding micromagnetic oscillations is also generally increased, is not observed.

Such a dependence of the amplitudes upon the period which we see distinctly for the micromagnetic oscillations of the first type seems to be of some interest.

II. RELATIVE FREQUENCY OF DIFFERENT PERIODS OF OSCILLATIONS.

For studying the relative frequency of the micromagnetic oscillations the records of the Observatory were examined in the following manner:

The periods (equal for all components) were divided into groups: (1) From 4 to 5 seconds; (2) from 5 to 7 seconds; (3) from 7 to 9 seconds, etc., and the number of times during the whole year was determined when periods belonging to each of the groups occurred. In such a manner the absolute frequency of the periods of each group is obtained, but for us not the absolute frequency, but the relative one, is of interest, and therefore we express this number in percentage of the whole number of cases for the component observed.

If we designate by n the absolute frequency of the periods of the group given, by Σ_n the total number of cases for the component, i. e., the sum of the absolute frequencies of all groups, so the relative frequency of the group is given by

$$N = \frac{n}{\Sigma_n} 100$$

In Table 3 the results of these computations are indicated. Here are given the total number of cases Σ for each component.

TABLE 3.

Limits of T_p	N		Mean values	
	H	Z	T_p	N
s	%	%	s	%
4– 5	4.7	4.4	4.84	4.6
5– 7	40.5	41.2	6.02	40.9
7– 9	49.3	48.8	8.27	49.1
12–13	3.9	3.6	12.36	3.8
14–15	1.6	2.0	14.61	1.8
Σ	617	553		

The maximum for N % corresponds to the group from 7 to 9 seconds, while the mean T_p is about 8 seconds. The oscillations of the period of $4.^s84$ represent this peculiarity, that these small vibrations are frequently superposed on oscillations of a longer period.

III. DIURNAL AND ANNUAL VARIATIONS OF THE MICROMAGNETIC OSCILLATIONS.

Concerning the *diurnal frequency of the micromagnetic oscillations* the observations indicate that the waves of short periods (5–14 sec.) particularly appear during the day between 12^h–19^h, local mean time; at night waves of longer period appear (with period of 30–40 sec.). The oscillations are by day more changeable and not calm; at night waves of smaller amplitude and particularly oscillations with the period of 30–40 seconds are observed. One circumstance more is interesting: that a thunderstorm, or a heavy rain, passing over the region of observation seem to influence the micromagnetic oscillations of longer period, but do not affect the waves of type I.

The number of hours during the month in which the micromagnetic oscillations are observed have an annual variation with a maximum in March and minimum in July.

For studying the *annaul variation of the micromagnetic oscillations*, I computed the hourly average values of the periods and amplitudes (separately for the waves of types I and II). The resulting data are given in Table 4.

TABLE 4.

Months	T_p		A_H		A_Z	
	Type I	Type II	Type I	Type II	Type I	Type II
	s	s	γ	γ	γ	γ
Jan.	8.03	34.72	1.61	1.22	1.45	1.20
Feb.	8.27	34.06	1.83	1.19	1.61	1.18
Mar.	7.84	34.69	1.48	1.26	1.43	1.32
Apr.	7.27	33.77	1.28	1.37	1.34	1.25
May	7.12	34.61	1.17	1.28	1.19	1.20
Jun.	7.43	34.82	1.33	1.31	1.26	1.29
Jul.	7.41	33.52	1.26	1.29	1.21	1.30
Aug.	7.21	34.74	1.23	1.32	1.15	1.34
Sep.	6.74	34.66	1.05	1.25	1.07	1.20
Oct.	7.16	34.82	1.18	1.30	1.11	1.27
Nov.	7.86	34.14	1.58	1.19	1.43	1.26
Dec.	7.49	34.58	1.40	1.28	1.34	1.22

In this table (for the waves of type I) it is evident that the amplitudes of the micromagnetic oscillations increase in winter and autumn months and diminish in summer months, whilst this diminution is accompanied by a decrease of the corresponding mean periods.

This phenomenon is also observed for the microseisms by B. Galitzin (*l. c.*). For the waves of a longer period no such regularity is observed.

IV. SOME PECULIARITIES OF THE MICROMAGNETIC OSCILLATIONS AND THEIR SIMILARITY WITH THE MICROSEISMS.

As to the micromagnetic oscillations of type II, there is no doubt that they are in near dependence on the atmospheric-electric field; as to the micromagnetic oscillations of type I, some of them may have a common cause with the microseisms.

In this connection it is surprising that the oscillations of this type as is shown by the figures vary almost accordingly with the microseisms. Figures 1 and 2 represent the annual variation of the periods and of the amplitudes of the micromagnetic oscillations in Zouy, and those of the microseismic oscillations (in seconds and microns respectively) in Irkutsk, Tashkent, and Pulkova. Short periods are characteristic for these oscillations. This gives us the idea that we have to do with oscillations excited by an allied cause.

I restrict myself to these brief statements. The observations are still being continued, and further deductions and conclusions would be premature. For the further investigation of the micromagnetic oscillations, at the suggestion of Prof. T. Kravetz, an induction-coil of thin insulated wire which is closed on a very sensitive galvanometer was installed by me in Zouy. The oscillations arising in the coil are registered on photographic paper put on a rapidly rotating drum (1 min. = 30 mm.).

In conclusion, I wish to express my sincere thanks to Prof. T. Kravetz, Chief of the Seismological Station of Irkutsk, for his suggestion as to the installing of a special induction-coil for registration of small period waves, and for having put at my disposal seismological literature concerning microseismic movements.

Meteorological and Magnetic Observatory,
Irkutsk (Zouy), April 2, 1926.

ON MICROMAGNETIC OSCILLATIONS OF TYPE II.

By Arnold Pödder.

In my article "Micromagnetic Oscillations as Observed at the Magnetic Section of the Observatory of Irkutsk (Zouy), 1925," I considered the micromagnetic oscillations of type I, observed with the aid of the sensitive Eschenhagen magnetograph (the sensitiveness of the Lloyd's balance is 1 mm. $=1.3\gamma$; that of the apparatus for horizontal intensity is 1 mm. $=0.34\gamma$, and a velocity of rotation of the drum with the photographic paper is 1 min. = 15 mm.), and having periods from 4 to 15 seconds. As for the micromagnetic oscillations of type II, with periods averaging about 34 seconds, I calculated only the mean monthly values of the periods and the amplitudes for 1925.

Examination of this data revealed some regularity of a change of periods and amplitudes, consequently I decided to treat the above-mentioned observations in another manner, namely as Dr. W. van Bemmelen treated[17] micromagnetic oscillations or pulsations, as he denominates them, for Batavia and Buitenzorg.

[17] W. van Bemmelen. Erdmagnetishe Pulsationen. *Met. Zs.*, Braunschweig, Hann-Band 1906 (268-270).

W. van Bemmelen. On pulsations. Appendix to observations made at the Royal Magnetical and Meteorological Observatory at Batavia, v. 29, 1906. Batavia, 1908.

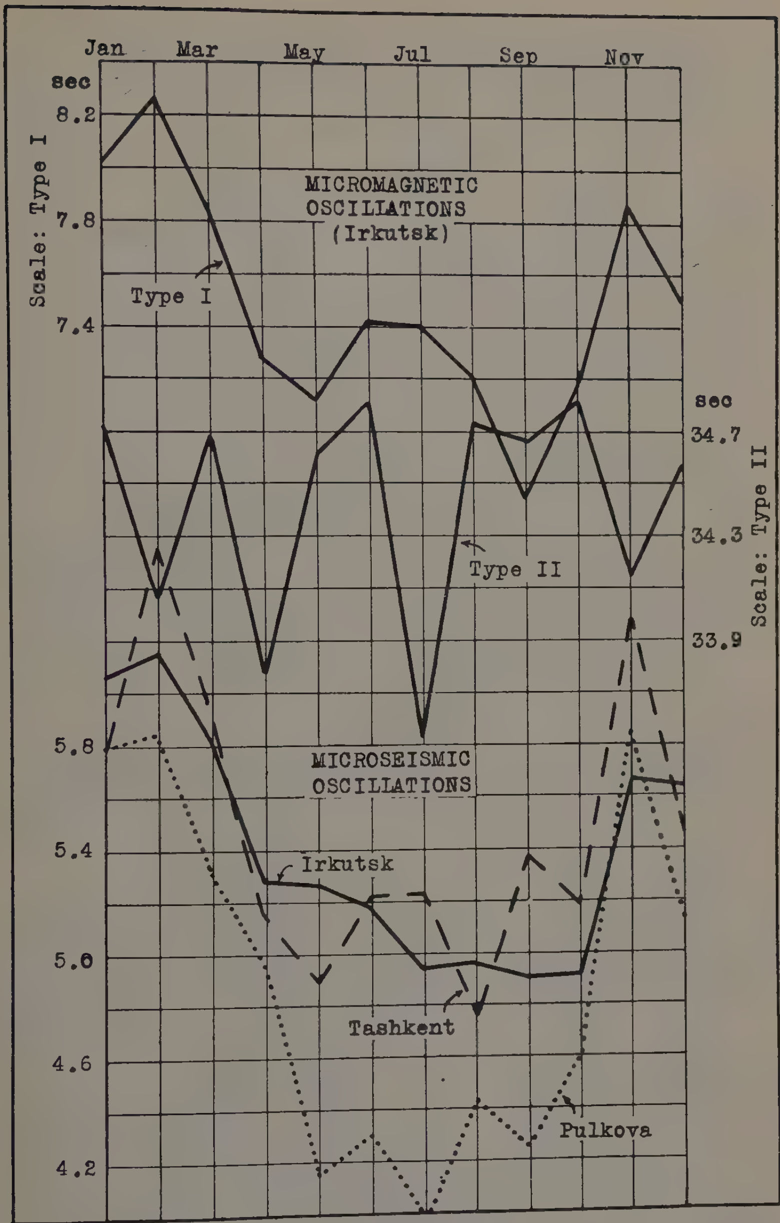

Fig.1 (see p. 108, IV).

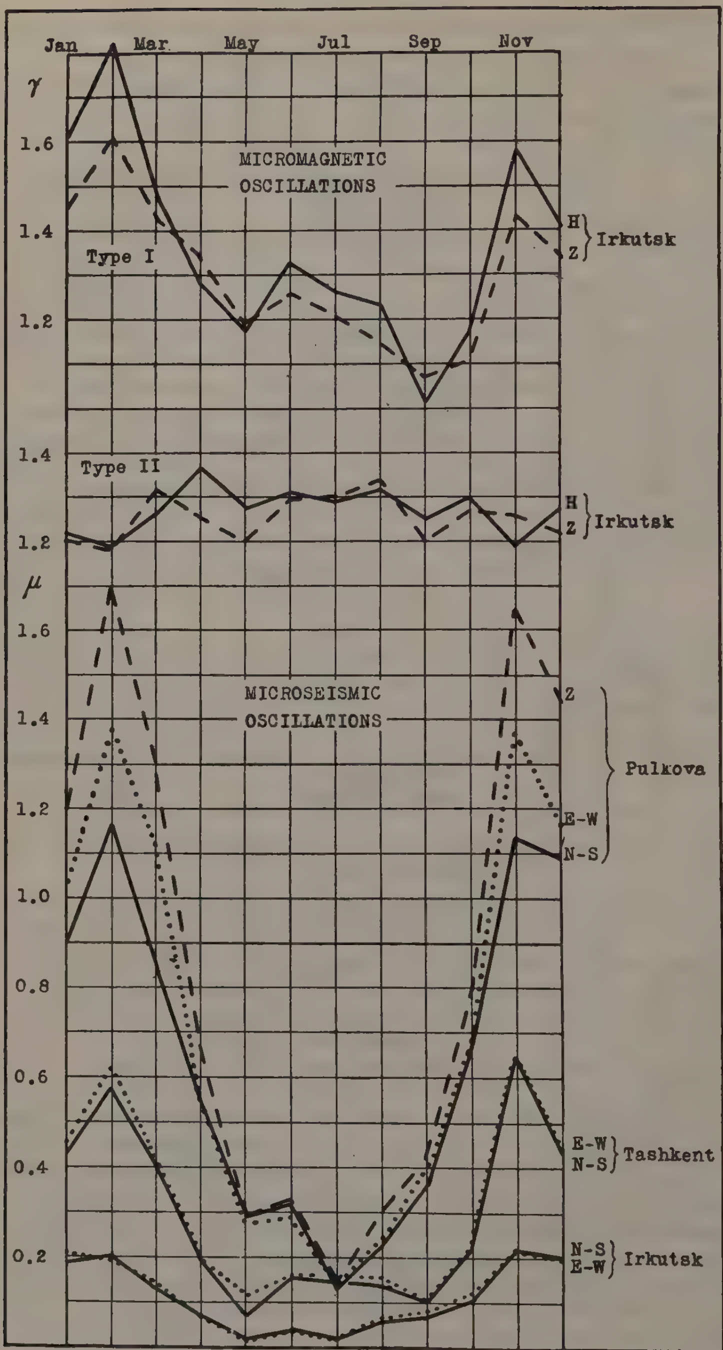

Fig. 2 (see p. 108, IV).

The micromagnetic oscillations of type II filled on the horizontal-intensity trace 287 hours and on the vertical one 279 hours in 1925. To clear the diurnal range of micro-oscillations, I calculated the mean duration of the oscillations in seconds for every hour during twenty-four hours. The results of this calculation are given in Table 1.

TABLE 1.

El.	0^h–1^h	1^h–2^h	2^h–3^h	3^h–4^h	4^h–5^h	5^h–6^h	6^h–7^h	7^h–8^h	8^h–9^h	9^h–10^h	10^h–11^h	11^h–12^h
H	143	151	159	150	144	143	149	141	140	139	139	140
Z	140	147	154	150	141	143	143	144	137	137	140	136
El.	12^h–13^h	13^h–14^h	14^h–15^h	15^h–16^h	16^h–17^h	17^h–18^h	18^h–19^h	19^h–20^h	20^h–21^h	21^h–22^h	22^h–23^h	23^h–24^h
H	142	144	140	131	131	127	144	138	144	140	139	142
Z	140	144	139	134	125	130	136	139	147	143	142	140

Table 1 shows the *period of oscillation* varies about a mean of 141 seconds during 24 hours. At night the oscillations are more frequent than by day, and the maximum occurred directly after midnight, and the minimum by day about 16^h–18^h.

To determine the *annual range of the micro-oscillation*, I counted the number of hours in each month in which the oscillations of horizontal and vertical intensities occurred.

TABLE 2.

El.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
H	25	31	37	26	23	22	17	14	21	22	24	25
Z	24	30	35	28	21	17	19	13	20	23	26	23

Table 2 shows that the maximum occurred in March, and the minimum in August. This circumstance does not quite agree with the deduction of Dr. W. van Bemmelen, that the range of a pulsation in North and South Hemispheres is opposite, as indicated in the following presentation:

		Potsdam	*Batavia*	*Zouy*
Annual range	*Max.*,	June, July	December	March
	Min.,	December	July	July, August
Diurnal range	*Max.*,	about $12^h\ 50^m$	6^h–10^h	1^h–3^h
	Min.,	at night hours	at noon	16^h–18^h

One interesting peculiarity of the micro-oscillations of type II is the appearance of "groups of waves," explained probably by superposing one system of oscillations on another having a slightly different period. For the horizontal intensity this phenomenon is more pronounced.

It is probable that the forces producing micro-oscillations have a periodic character and, through mutual action, produce the phenomenon of the oscillations' interference.

That is, in general, the phenomenon of the micro-oscillations of type II. Leading to new ways of investigating the Earth's magnetic forces, it has many obscurities and contradictions. This is probably because the micro-oscillations observed at different places and at different times are not consistent; the variation in amplitudes and periods indicates it.

For explaining its nature and cause, it is necessary to make a detailed investigation of this phenomenon.

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Meteorological and Magnetic Observatory,
Irkutsk (Zouy), May 7, 1926.

PRELIMINARY COMPARISON OF ATMOSPHERIC-ELECTRIC POTENTIAL AT SEA WITH THAT UNDER CLOSELY SIMILAR INSULAR CONDITIONS AT APIA, WESTERN SAMOA.

By Andrew Thomson.

The electric potential of the atmosphere has been measured at Apia (latitude 13°.8 S., longitude 171°.8 W.) for 19 years[1], and on account of the unique position of the Observatory on a small island in the Pacific Ocean, special interest has been attached[2] to the results in giving information concerning the great water-covered areas of the Globe. In order to approximate more closely to oceanic conditions, the Department of Terrestrial Magnetism of the Carnegie Institution of Washington erected, in 1923, above the waters of the lagoon, a special observation-house about 500 meters from the shore. The house is on the north side of the island, in a position exposed to the winds, but protected by a narrow ridge of coral reef from the action of the waves of the open ocean. The Southeast trades, shifted by local conditions so that they blow parallel to the north coast of the island[3] have not passed over land before striking the lagoon house, and the atmosphere, being that of an oceanic island, is free from dust or pollution.

The house itself, of which the interior dimensions are 3.85 meters x 2.6 meters, with a height of 2.5 meters at the eaves (Fig. 1), is built on concrete piers resting on coral rock in shallow water about 0.6 meter deep at low tide. The building is covered with a slightly arched iron roof connected by a wire to the water. The walls are of asbestos board, strongly braced, which, except for the visitation of this vicinity by a cyclone, should remain for many years.

Although this site eliminated any possible change of surroundings by growth of trees and erections of buildings, it was feared that the reduction of the observed potentials would be complicated by the changing equipotential surfaces brought about by the tide, which has at Apia a range of about 0.7 meter neap, and 1.2 meter spring. In order to reduce this tidal effect, there was erected under the collector a platform of 7.65 square meters. A tide gauge of the portable automatic type[4] has been installed and continuous records have been obtained. Daily measurements are also taken of the density and temperature of the sea water.

The collector used is a copper disk covered with ionium protected by a thin layer of Bakelite lacquer. The collector is mounted 1.36 meters from the wall of the house and 2.08 meters above the platform described in the previous paragraph. A Benndorf electrometer, recording every two minutes, is used and maintained at a sensitivity of about 185 volts per cm.

Although the distance from the shore is small, and the water nowhere more than 3 meters deep, in spells of squally weather it has been impossible on occasions lasting several days to visit the house. In these squalls, which fill the air with spray penetrating everywhere, insulation breaks down. For the first year amber rods 15 cm. long were used to support the copper pipe to which the ionium collector was fastened. Moisture collecting on the amber rods made the insulation imperfect, and records were so interrupted that use has not been made of them in this report. *Attention should be drawn to the fact that frequently quoted data*[5] *of the diurnal variation and of the mean annual values based on early observations*[6] *of the potential gradient at Apia are in absolute error on account of inferior insulation of the apparatus.*

A special insulating support consisting of a thick-walled sulphur cylinder, designed by the Department of Terrestrial Magnetism and made up in its shop, has been found tolerably satisfactory even in the hot and damp climate of the Samoan islands. Any records which might be suspected of the slightest impairment of the insulation were discarded. Whenever this should have resulted in a hiatus in the records greater than 3 hours, the data for the whole day were discarded.

Simultaneous with the observations of atmospheric potential at the lagoon house, records have been obtained at a station in the Observatory grounds, described in a previous number of this Journal.[7]

The only days considered in this *preliminary study* were those free from negative electricity, and for which complete records were available at both stations. However, in view of the paucity of information in regard to negative electricity, it may be well to give first of all an idea of its occurrence at Apia.

NEGATIVE ATMOSPHERIC ELECTRICITY AT APIA.

The total duration of negative potential for the eight months, February to September, 1925, inclusive, at the land station for which records are complete was 230 hours. Because of interruptions of records, brought about by faulty insulation, its exact duration at the lagoon house cannot be determined, but its probable occurrence can be arrived at best by considering those times (over 90 per cent of the whole) for which simultaneous records for both stations are available. When negative electricity occurred during an hour it was tabulated as a negative hour, even if the duration were only sufficiently long to be registered by the electrograph. In Table I the number of negative hours for which simultaneous records are available is given.

Thus it is seen that the lagoon house, although only 590 meters from the land station, shows an occurrence of negative electricity only eight-tenths as frequent as the land station. This result

TABLE 1.—*Hourly periods during which negative electricity occurred at land station and lagoon house, Apia, with number simultaneously occurring at both stations, February to September,* 1925.

Station	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Total
Land.......	127	117	80	50	42	11	12	12	451
Lagoon......	113	79	69	39	26	7	7	7	347
Both........	89	57	44	26	23	6	3	6	254

Fig. 1.—Lagoon House, Apia Observatory.

was unexpected, because not only rainstorms coming down from the northwest sweep over the lagoon house first, but also lightning and thunder are more commonly observed out to sea than inland. However, cumulus clouds with their charges are almost invariably to be seen over the peaks of the range of hills some 6 kilometers inland, and it is possible that sometimes the negative field from the clouds extends out to the shore, but not as far as the lagoon house.

The diurnal distribution of negative electricity throughout the 24 hours is given in Fig. 2. The hours of most frequent occurrence, from 14^h to 18^h (6 p. m.), are those during which rain falls for the greatest proportion of the time[8].

Negative electricity has been observed rarely at sea, because the insulation of the electrometers and apparatus breaks down in the shower. This probably accounts for Kidson's observations[9], and Swann's[10]. The writer, who was observer-in-charge of the atmospheric-electric work on the non-magnetic yacht *Carnegie*, 1919-1921, found that on several occasions far out at sea, after the first few drops of rain, very high values of negative electricity occurred. On account of the insulators becoming wet the observations could not be continued, because bringing the insulation to a satisfactory condition was impracticable while the rain was still falling. However, as has been found at the lagoon house, it is probable that negative electricity occurs in conjunction with showers at sea and not necessarily with thunderstorms which, at least during the writer's experience of 485 days spent on the high seas during the *Carnegie's* cruise of 1919-1921, were extremely rare.

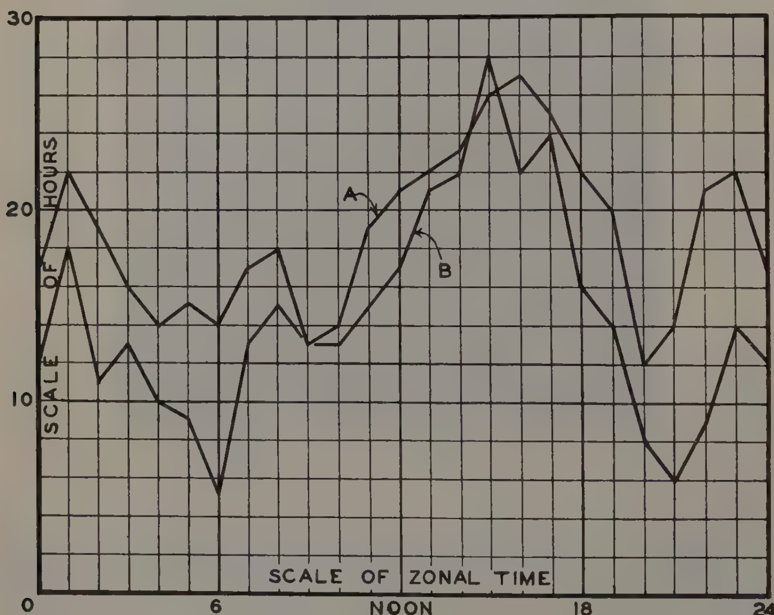

Fig. 2.—Frequency of Occurrence of Negative Electricity during Day at Apia Stations, February to September, 1925; A = Land Station, B = Lagoon House.

POSITIVE ATMOSPHERIC ELECTRICITY AT APIA.

In Table 2 and Fig. 3 are given the mean hourly values of the potential at the lagoon house for those days free from negative electricity at both stations, and for which complete and simultaneous records are available. The hourly means for each station are computed from the hourly values of all days acceptable according to the restrictions mentioned above—a total of 57 days during February to September, 1925, inclusive. It is not an average of the monthly means at each station. The values of the potential gradient at the land station are in volts per meter. The reduction factor for these observations has been determined on numerous occasions and may be confidently relied on. It is seen that the

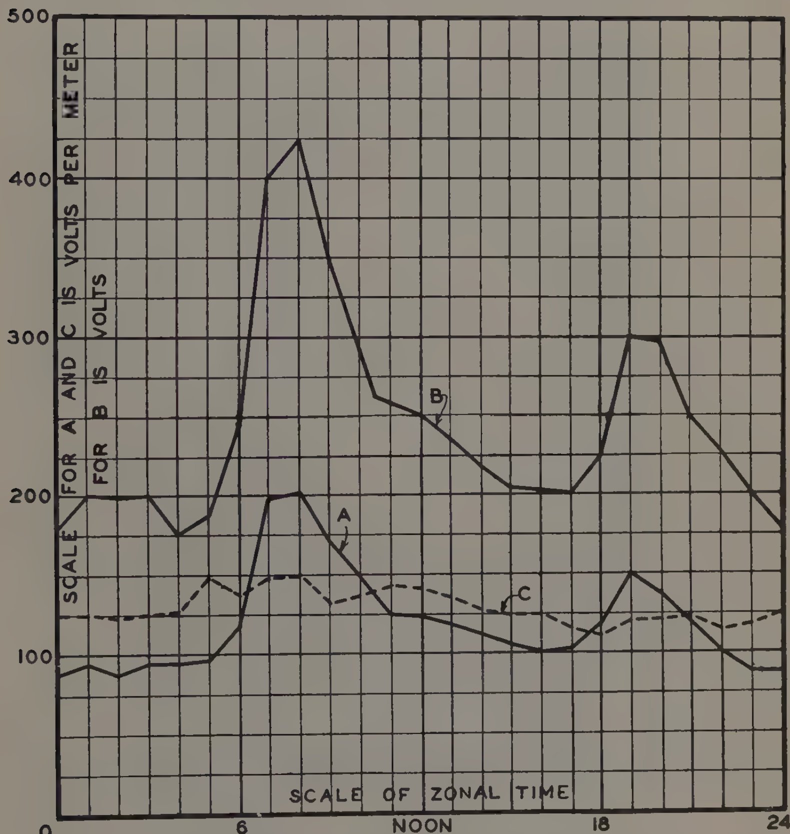

Fig. 3.—Diurnal Variation of Potential Arranged According to Zonal Time (at Apia 27.1 Minutes Fast on L. M. T.); A = Land Station, Apia; B = Lagoon House, Apia; C = *Carnegie* Observations in the Tropics in the Pacific Ocean.

TABLE 2—*Atmospheric potential for days without negative electricity as recorded at the lagoon house station, Apia Observatory, Western Samoa, February-September, 1925, expressed in volts.*

[The tabular values are average values for successive hourly periods, zonal time, 165th meridian, West, which is 27.1^m fast on local mean time.]

Month	No. days	0h-1h	1h-2h	2h-3h	3h-4h	4h-5h	5h-6h	6h-7h	7h-8h	8h-9h	9h-10h	10h-11h	11h-12h	12h-13h	13h-14h	14h-15h	15h-16h	16h-17h	17h-18h	18h-19h	19h-20h	20h-21h	21h-22h	22h-23h	23h-24h
Feb.	3	139	147	143	154	151	155	218	357	258	231	227	230	227	234	253	210	201	194	256	249	245	207	144	134
Mar.	3	186	221	167	164	137	151	240	441	516	382	267	241	248	225	214	203	207	213	227	300	317	241	223	159
Apr.	3	213	223	218	228	228	257	312	420	550	416	292	255	223	219	189	233	209	184	214	392	363	293	392	283
May	7	146	162	167	185	159	156	187	266	338	293	248	232	234	210	213	213	211	188	246	439	332	228	180	141
Jun.	6	142	148	142	184	162	156	264	428	516	432	386	300	259	237	224	233	209	196	225	282	236	195	144	140
Jul.	6	112	139	118	135	140	145	204	363	426	346	277	245	251	246	215	194	212	205	221	226	261	254	224	192
Aug.	15	248	277	269	253	229	237	274	445	417	365	294	282	268	257	235	220	215	200	221	306	294	268	269	233
Sep.	14	165	171	176	171	153	171	230	387	418	320	283	262	230	217	201	192	185	194	212	248	309	256	238	208
Mean*		179	196	190	194	176	185	241	392	423	347	288	263	246	233	218	210	205	197	224	298	295	248	230	195
Ratio†		0.50	0.46	0.47	0.46	0.51	0.50	0.48	0.50	0.49	0.48	0.51	0.49	0.50	0.51	0.51	0.51	0.51	0.53	0.53	0.51	0.47	0.48	0.43	0.46

* Weighted according to number of days of observation per month.
† Land station to lagoon house for simultaneous days of observation.

ratios of hourly values, land station to lagoon house, given at the bottom of the table, approximates 0.49, and this ratio shows no marked change throughout the day. That is, the observations at the lagoon house show the double maxima found at the land station (7). There is no conspicuous effect due to the sea. The electrical forces at the land station are seen to operate at least a short distance out to sea.

Dr. S. J. Mauchly has discussed[11, 12] observations taken on the non-magnetic yacht *Carnegie*, including those taken by the present writer on Cruise VI, and finds that the diurnal variation of the potential gradient "over the oceans is primarily due to a 24-hour 'wave,' which progresses approximately according to universal rather than local time." All the observations taken within the tropics[12] in the Pacific Ocean have been plotted according to zonal time (165° W. of Gr). In the tropics the characteristic daily curve does not change noticeably with the change of season as it does, for example, at Eskdalemuir and the Bureau Central, Paris. On this account it is permissible to take out hourly means, irrespective of the season at which the records were made. The results of the ocean data shown in Fig. 3 give a curve of an entirely different character. The wide difference between the results at sea and on land cannot be attributed to difference in height of collector, since the collectors were practically at the same height on the *Carnegie* and at the lagoon house. Conditions of relative humidity, air temperature, purity of air, cloud conditions, mentioned by F. J. W. Whipple[13] as a possible cause for the differences between ocean and land observations, approximate closely, at Apia, to those prevailing for the *Carnegie* while in the tropics. Nor does the personal equation enter, as a majority of the *Carnegie* observations in the tropics and those here at Samoa were taken by the same observer. It may be pointed out that practically every one of the 57 days here at Samoa distinctly showed double maxima, whereas of the 20 *Carnegie* observations only 3 were double, 3 were mixed, and 14 gave a single maximum. Apart from any grouping according to universal time as arranged by Dr. Mauchly, there is a fundamental difference in each individual day's observation between those at sea and those taken in similar surroundings at the lagoon house. Seemingly some subtle influence is introduced by the presence of land, even of very small area. Upolu Island has an area of 868 sq. km. (320 sq. miles), and the water-covered area within a 2,000-km. radius is over 99 per cent of the whole. On only one atmospheric-electric element has land been found to have a marked effect, that is, on the quantity of radio-active material in the air, which almost invariably increases as land is approached.

Some of the observations on the *Carnegie* taken nearest to land do not show any indication of this 12-hour wave, and it is an open question how far out to sea from land does the character of the wave change.

When the mean hourly values of the lagoon house have been multiplied by 0.49 to convert them to their equivalent values if taken over level ground, the Fourier analysis of the 24 mean hourly values gives $P=120+20.7\sin(\theta+128^\circ.9)+33.0\sin(2\theta+216^\circ.0)+7.4\sin(3\theta+280^\circ.6)+19.7\sin(4\theta+12^\circ.1)+5.9\sin(5\theta+100^\circ.3)+9.0\sin(6\theta+182^\circ.7)$. The angle θ is counted from midnight G. M. T., which is 1 1 hours and 27 minutes fast (171°.8 W. of Gr.) on local time at the rate of 15° per hour. The ratio of the coefficients of the 12-hour term to the 24-hour term, $c_2/c_1=1.6$, while Dr. Mauchly has found for sea observations arranged according to universal time a value of 0.25[11] for this ratio. A high value for 6-hour term is in agreement with results for Kew[14] and Ebro.[15]

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SWINGING SHIP FOR THE PRECISE DETERMINATION OF DEVIATIONS IN MAGNETICALLY-DISTURBED HARBORS.[1]

By William J. Peters.

In the ordinary method of swinging ship, the vessel is held on the selected headings successively as for example, E, SE, S, SW, W, NW, N, and NE and on the swing with the other helm the order is reversed, NE, N, NW, W, SW, S, SE, and E. When the region is magnetically disturbed and the highest precision is sought there are two points to be considered.

a. In making a swing under ideal working conditions, that is perfectly calm weather, absolutely smooth water, with no current, and spending the same amount of time at uniform speed on each heading the vessel's course throughout the swing will describe a regular polygon as in Figure 1 in which the vessel on port swing, heads E from *D* to *E*, SE from *E* to *F*, etc., and on the starboard helm NW from *F* to *E* and W from *E* to *D*, etc. If the swings with both helms are made under these ideal conditions at the same speed and spending the same amount of time on each heading, the vessel will pass over the same bottom on *opposite* headings of the two swings, and the results for any two opposite headings of the two swings would be strictly comparable as regards irregular distribution of the local disturbance. This statement would not, however, hold for any other headings.

b. The ideal conditions, premised under *a*, are never realized in the rather long swings required for precise determinations of deviations and rarely, if ever, on the shortest swings. Usually the course during a swing is not a closed polygon but rather a figure of unequal sides the beginning and end of which may be separated by a distance of a mile or more. It is thus impossible to eliminate the effects of local disturbance which may be different on various headings.

The following method by which the course during a swing describes a rosette will give results that are practically free from changes in a uniform distribution of local disturbance even under conditions somewhat adverse. The method is illustrated by Figure 2 for a port swing of eight headings beginning with heading N. The swing for any other number of headings or with the starboard helm can be readily planned on the same principle.

A buoy is anchored at the point *C* selected for the center of the swing and the vessel passes over this point in the middle of each heading. But in order to economize time the headings are not made in the *boxing-the-compass* order and reverse, but the vessel, after holding one heading, N, from *A* to *B* for example, is turned with

[1]This method of swinging ship has already been used and described by Commander G. T. Rude, *U. S. Naval Inst. Proc.*, Aug., 1926, pp. 1492-1495. As it has some additional advantages, especially in magnetically-disturbed harbors, it was thought desirable to publish the paper as originally written.—W. J. P.

the proper helm (port, in the figure) through *one half the total number of headings* 8 that are to be held, NE, E, SE, and S, and is held on the next, SW, from *D* to *E* and so on. In order to pass by the buoy at the middle of the distance sailed on each course, the effects of wind and current will have to be estimated carefully.

It is evident that if the local disturbance varies uniformly over the area covered by the rosette, the results for each heading will be the value of the magnetic element at the point *C*, and this will be true even when wind and current make the actual course over the bottom different from the heading by compass, provided the effects of these are allowed for in manœuvering.

Figures 1 and 2 are drawn to the same scale, that is, the length of the course on each heading is the same in both figures. They show the relative dimensions of the swings by the two methods. The *rosette* takes about one-third the area or searoom required by the ordinary method of swinging.

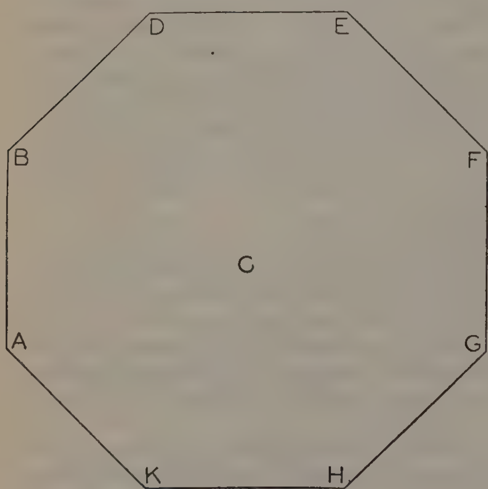

Fig. 1.

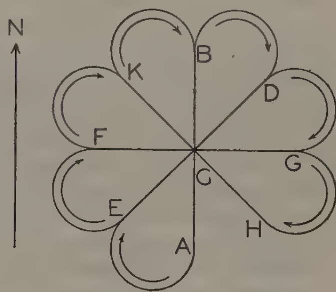

Fig. 2.

The time required to make a swing will be about 1.6 times longer for the *rosette* method than for the ordinary method, but this might be reduced considerably by running slow on headings held for observations and fast on the turns between.

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
July 10, 1926.

CONSIDERATIONS ON MEASURES FOR MAGNETIC ACTIVITY.

By Boris Weinberg.

I would like to point out at first that the very name "magnetic activity" is ill chosen because there is no doubt that the aperiodic magnetic variations are due to some agency differing from terrestrial magnetism itself, for instance, to changes in Earth's currents or to atmospheric-electric currents, or to currents of electrons emitted by the Sun, etc. Therefore from the physical standpoint we must try to find a measure for the *intensity*, A, of this very agency, its mean value $\overline{A}$ being the real cause of the variability of magnetic force, for instance, the agency being some current it is the intensity of the current.

If we do not wish to be influenced by the words it would be more adequate to speak about *magnetic variability*, but not about *magnetic activity*, reserving the word *activity* for the action of the agency causing these phenomena. This activity being beyond our means of observation we are obliged to estimate its amount according to the variations of the observed values of magnetic element at a number of stations.

Let us suppose that the geometrical difference of the total magnetic force T and the *normal* force T_0 is proportional to the intensity A of the disturbing agency at this moment. Denoting the three components of T, of T_0, and of their geometrical difference by X, Y, Z, X_0, Y_0, Z_0, and $\triangle X$, $\triangle Y$, $\triangle Z$[1], respectively, we thus assume that instantaneous values of $\triangle X$, $\triangle Y$ and $\triangle Z$ are proportional to the instantaneous value of A.

If we desire to characterize the activity of the agency for certain interval of time $t=t_1-t_0$, the physical standpoint would recommend taking the time-integral $\int_{t_0}^{t_1} A\,dt$, the integration being fulfilled on the numerical or in other words arithmetical values of A. If for instance A is the intensity of sun-electrons current this integral must be made equal to the arithmetical sum[2] of all the quantities Q_+ and Q_- of electricty which flow in either direction through a definite surface S. If we take a definite value of $t=t_1-t_0$, say a day a month or a year, we may evaluate the activity by a mean value of A, *i.e.*,

$$\overline{A}=\frac{1}{t_1-t_0}\int_{t_0}^{t_1} A\,dt \tag{1}$$

[1]Charles Chree, *Terr. Mag.*, vol. 28 (1923), pp. 33-40; *Trans. Rome Meeting*, pp. 107-114, 1923.

[2]Of the same type is the D-measure of sunspottedness introduced by L. A. Bauer, *Terr. Mag.*, vol. 26 (1921), p. 47.

As A can not be measured we should take as a measure of magnetic variability

$$V_m = \sqrt{|\overline{\Delta X}|^2 + |\overline{\Delta Y}|^2 + |\overline{\Delta Z}|^2} \tag{2}$$

where $|\overline{\Delta}|$ denotes the averaged absolute value of Δ if we adopt the above-mentioned agreement and the supposition of proportionality of ΔX, ΔY and ΔZ to A.

We may as well combine these assumptions with Bildingmaier's proposition to take as a measure of magnetic variability the variations of the volume-energy of the magnetic field, but with an essential change which eliminates all doubts concerning the *excess-energy*. Bildingmaier and others take into account the *final* change of the integral of the *joint-energy*[3]

$$|I_1| + \frac{1}{4\pi}\iiint \left\{ X_0\Delta X + Y_0\Delta Y + Z_0\Delta Z \right\} dx\, dy\, dz \tag{3}$$

during a certain interval of time or the range of these changes in order to minimize computations.

If we desire to characterize the variability of the volume-energy we must take not the result of its variation—their algebraical sum—but their arithmetical sum[4]

$$|I_1| = \frac{1}{4\pi}\iiiint \left\{ |X_0\Delta X| + |Y_0\Delta Y| + |Z_0\Delta Z| \right\} dx\, dy\, dz\, dt \tag{4}$$

Although the *self-energy* I_2 must in such a conception be usually much less than I_1, we can easily consider both and take finally as a meaure for magnetic variability

$$|I_1| + I_2 = \frac{1}{4\pi}\iiiint \left\{ |(X_0 + \tfrac{1}{2}\Delta X)\Delta X| + |(Y_0 + \tfrac{1}{2}\Delta Y)\Delta Y| + |(Z_0 + \tfrac{1}{2}\Delta Z)\Delta Z| \right\} dx\, dy\, dz\, dt \tag{5}$$

In order the characterize the magnetic variability at a certain station during a definite interval of time t by the change W_m of volume-energy we might therefore calculate it by using the following formula

$$W_m = |(X_0 + \tfrac{1}{2}\overline{\Delta X})\,\overline{\Delta X}| + |(Y_0 + \tfrac{1}{2}\overline{\Delta Y})\,\overline{\Delta Y}| + |(Z_0 + \tfrac{1}{2}\overline{\Delta Z})\,\overline{\Delta Z}| \tag{6}$$

Such a measure of variability satisfies fully the conditions 3, 4, 5 and 6 of those enumerated in A. Crichton Mitchell's article in the "Transactions of Madrid Meeting" (pp. 46-48, 1925).

As to conditions 1 and 2 they depend fully on the evaluation of

[3]S. CHAPMAN. *R. A. S. Notices*, vol. 79 (1919), p. 70.

[4]The necessity of taking arithmetical means was implicity advocated by L. A. BAUER, *Terr. Mag.*, vol. 26 (1921), p. 56, although in a paradoxical form of the dt's varying in sign as well as the values of ΔX, ΔY and ΔZ, what can not be applied to I_2.

X_0, Y_0 and Z_0. I should venture that the condition 2 of Mr. Mitchell be made more vigorous and would replace it by a statement that any measure of magnetic variability which has to be adopted must be independent of the regular diurnal variation.

It seems unreasonable to strive for a quantitive measure which has to "ultimately replace the present international scheme of character numbers"[5] and which could be determined with a precision of more than some 5-10 per cent. A greater precision is easily attained for *ranges* (even for the hourly ones on not very quiet days) but Mr. Mitchell is quite right when he says about the mean value for the 24 hours of Σr^2 that "its exact numerical relation is, I admit, somewhat doubtful." This opinion may hold for the difference of the maximal and minimal values of *any* physical quantity, these values being of the nature of freaks which are to be placed rather in old "Kunstkammern" ("cabinets of rarities") than in a modern scientific museum. Therefore a measure like W_m, although it can not be determined as precisely as a range owing to an unevitable arbitrariness of X_0, Y_0 and Z_0, seems to me to be quite adequate.

The uncertainty in the evaluation of W_m diminishes when we diminish t, but the diminution of t involves necessarily a considerable increase of computations. I should say that the hourly intervals are simultaneously the maximum as concerns the diminution of uncertainty of W_m and the minimum as concerns the increase of the difficulties of computations.

As one of the best methods of excluding the diurnal variations and a method quite appropriate for our purpose is the one adopted by Birkeland in his studies on polar magnetic storms[6] namely, "the normal line (on a magnetogram) will be a line that connects the calm districts before and after in such a manner that its further course is ruled by the curve on the nearest calm days."

In order to compute $\triangle X$, $\triangle Y$ and $\triangle Z$ (or $\triangle H$, $\triangle D$ and $\triangle V$) for each of the 24 hours with maximal precision we ought to measure by means of a planimeter all the "tongues" of a magnetogram lying over and under the normal line but if we remember that we desire to find the average deflection with a precision of some 5-10 per cent of its value, the measurement of a magnetogram may be made in a much simpler and quicker way.

For estimation of the amount of work needed for the most troublesome part of computing W_m—the finding of $\triangle H$, $\triangle D$ and $\triangle V$—I made a test by finding these mean values for each of the 11 hours of February 8, 1903, for which the magnetograms are given in the work of Mr. Birkeland[7] for 10 stations. I used transparent millimeter-paper and measured thereby the mean deflections of the normal line with a precision of some 0.1—0.2 mm. for not too great perturbations and with a precision of 0.5 mm.

[5] *Trans. Madrid Meeting*, p. 45, 1925.

[6] K. R. Birkeland. *The Norwegian Aurora Polaris Expedition, 1902-1903*, vol: I, sec. 1, p. 46, 1908.

[7] *l. c.*, pl. XVII.

TABLE 1.

Station		h h 13–14	h h 14–15	h h 15–16	h h 16–17	h h 17–18	h h 18–19	h h 19–20	h h 20–21	h h 21–22	h h 22–23	h h 23–24
Dyrafjord	ΔH	32	57	72	93	62	79	194	73	82	60	14
	ΔH	32	62	69	90	65	78	186	78	77	59	13
	ΔD	19	13	20	13	4	23	146	78	77	24	4
	ΔV	13	13	13	17	3	61	148	148	124	93	48
Axeløen	ΔH	26	68	55	51	100	80	393	229	106	41	3
	ΔH	29	64	55	52	110	82	389	245	102	44	3
	ΔD	32	45	39	30	17	38	81	74	35	7	4
	ΔV	18	21	6	4	52	62	279	366	248	133	50
Kaafjord	ΔH	10	79	33	94	43	44	168	175	94	16	4
	ΔH	11	85	35	88	41	46	171	183	92	15	5
	ΔD	6	32	12	16	22	14	73	103	59	17	3
	ΔV	5	41	62	46	58	34	292	315	114	58	18
Matochkin Shar	ΔH	..	96	43	69	60	47	274	254	164	18	7
	ΔH	..	92	41	72	60	48	280	246	153	19	7
	ΔD	..	50	14	39	23	18	132	135	109	33	8
	ΔV	..	44	13	98	35	102	71	81	61	32	15
Pavlovsk	ΔH	4	29	15	22	14	21	51	14	34	22	4
	ΔH	4	29	16	20	13	22	48	15	31	19	4
	ΔD	21	27	15	25	12	4	24	50	62	22	3
	ΔV	0	6	15	7	4	1	25	25	25	9	0
Val Joyeux	ΔH	1	22	21	16	21	22	35	22	43	32	7
	ΔH	1	20	19	16	22	19	34	20	42	34	7
	ΔD	3	14	4	10	11	10	57	50	24	11	1
	ΔV	0	1	0	0	0	0	2	1	0	0	0
Wilhelmshaven	ΔH	5	30	20	29	20	39	53	31	56	33	17
	ΔH	4	29	1	30	19	37	52	31	58	33	18
	ΔD	30	57	16	16	16	16	75	63	37	14	1
	ΔV	0	1	2	0	2	0	3	0	0	0	0
Potsdam	ΔH	3	38	27	33	22	43	40	30	64	47	25
	ΔH	4	35	26	31	23	42	42	27	58	46	25
	ΔD	3	11	8	13	15	6	65	67	38	14	0
	ΔV	0	0	4	0	4	0	0	22	0	0	0
Munich	ΔH	1	25	22	23	14	25	28	14	34	31	13
	ΔH	1	27	23	21	13	26	26	14	35	28	12
	ΔD	1	4	1	4	11	2	48	53	32	15	1
	ΔV	0	0	0	0	0	0	0	0	0	0	0
Pola	ΔH	1	36	30	30	21	31	31	17	42	30	12
	ΔH	1	36	31	30	23	34	29	18	40	32	13
	ΔD	16	22	8	13	3	6	40	48	25	4	1
	ΔV	1	3	0	1	5	2	12	4	1	0	0

for greater ones for each tenth of an hour which happily was equal to 1 cm. on all the magnetograms. In order to see the precision which such a method of evaluation of the $\overline{\triangle}$'s is liable without extreme expenditure of energy and time (the average interval of taking the 110 differences, $|\triangle|$, and computing the 11 averaged differences, $\overline{\triangle}$, in gammas, was about 13 minutes). I have repeated independently all the measurements and computations on the most disturbed element—*H*. The results are tabulated in Table 1.

The mean difference of two evaluations of the $\overline{\triangle H}$ in Table 1 is $\pm$ 2γ, which is equal to 4 per cent of the average value of the $\overline{\triangle H}$ themselves. Such a precision is about 8 times greater than the international character numbers and would amply justify the extra expense of some 30 minutes each day. I am sure that such a time will be fully sufficient in case of using proper appliances. A glass-scale for measuring the differences, $\triangle$, and preliminary computed tables which should give for each element the values of

$$(E_0-200)\gamma\times H\gamma,\ (E_0-100)\gamma\times H\gamma,\ E_0\gamma\times H\gamma,\ (E_0+100)\gamma\times H\gamma, \text{ and } (E_0+200)\gamma\times H\gamma$$

for $H=1, 2, 3, \ldots 9, 10, 20, 30, \ldots 90, 100$, E_0 being the average value in gammas of the element at the station, with two or three significant figures would enable one to obtain very quickly the 24 values of W_m. This assumption is based on the fact that the case treated by me was a case of a severe storm and the scale-value of the diagram was different for each.

The extra expense of 30 minutes a day is about twice as great as the expense needed for evaluation of the mean value[8] of Σr^2, but then we should have a physical measure of magnetic variability which should satisfy the two desiderata of the official report of Mr. Mitchell and the 6 conditions of his personal opinion.

LENINGRAD CENTRAL GEOPHYSICAL OBSERVATORY.

[8] A. CRICHTON MITCHELL, *l. c.*, p. 47.

NOTES

18. *International Society for the Exploration of the Arctic Region by means of the Airship.*—According to a circular received from the chairman, Prof. Fridtjof Nansen, a meeting of this society will be held at Berlin, November 10-12, 1926. The subjects to be discussed are chiefly organization and statutes, investigational work in oceanography, meteorology, geology, biology, terrestrial magnetism and electricity.

19. *Godhavn Magnetic Observatory, Greenland.*—Supplementary information[1] has been received from Dr. D. la Cour, dated July 29, 1926, showing that excellent progress has been made, under Dr. Ljungdahl's direction, with the establishment and equipping of this new observatory. Two sets of registering instruments (*D*, *H* and *V*) have been in operation since last January, and very satisfactory records have since been obtained. Dr. Ljungdahl has returned from Greenland and Dr. Joh. Olsen has taken charge of the Observatory.

20. *Gerland's Beitraege zur Geophysik.*—It is a pleasure to note the reappearance of this valuable publication on geophysics, originally established by the late Professor Gerland. The new editor-in-chief is Prof. V. Conrad of Vienna, and the publishers are the Akademische Verlagsgesellschaft M. B. H. of Leipzig. Heft I of Band XV contains a number of articles of special interest to geophysicists.

21. *New Auroral Observatory in Northern Norway.*—The Rockefeller International Education Board has given to Norway a sum of about $74,000 for the building and equipping of this new observatory, and the Norwegian Government has decided to maintain the Observatory with an annual budget of about $12,000. The scientific work will be done in accordance with plans and instructions given by a commission consisting of Director O. Krogness (Geophysical Institute, Tromso), Professor C. Störmer (University, Oslo), Professor S. Saeland (University, Oslo), Professor L. Vegard (University, Oslo), and the future director of the new observatory.

22. *Personalia.*—We regret to record the death on July 10 of Prof. *Ernst Biese*, for many years director of the Meteorological Observatory of Helsingfors, Finland, and on July 23 of Colonel *Francises S. Chaves*, the well-known director of the Meteorological Service of the Azores.

Among the King's birthday honors list we find noted in *Nature* the following: *K. B. E.*, Sir *Frank W. Dyson*, Astronomer Royal; *Knight*, Colonel *H. G. Lyons*, Director of the Science Museum; *C. B.* (Commander of the Bath), Dr. *G. C. Simpson*, Director of the Meteorological Service, and Mr. *F. E. Smith*, Director of Scientific Research of the Admiralty.

Mr. *J. Shearer*, formerly observer at the Watheroo Magnetic Observatory, has been awarded the Master of Science degree at the Melbourne University with first-class honors. He has also received an appointment as Evening Lecturer in Natural Philosophy at Melbourne University and is continuing his research work and tutoreal teaching in the University colleges.

[1] See *Terr. Mag.*, vol. 30 (1925), note 29, p. 153.

EIN BEITRAG ZUR FRAGE DER SCHEINBAREN FORTPFLANZUNGSGESCHWINDIGKEIT ERDMAGNETISCHER STÖRUNGEN.

Von R. Bock, *Potsdam.*

C. Chree[1] gibt die Anregung, bestimmte erdmagnétische Observatorien mit geeigneten Registrierapparaten auszurüsten, um Material zu schaffen für die Untersuchung der Frage, ob sich die erdmagnetischen Störungen mit einer kleineren Geschwindigkeit als die des Lichtes fortpflanzen and welche Richtungen sie in diesem Falle bevorzugen. Das erdmagnetische Observatorium Potsdam unterhält bereits seit Anfang 1925 eine derartige Registrierung, deren nähere Beschreibung schon anderen Ortes[2] erfolgt ist. Die Ergebnisse einer nach der Richtung unternommenen Auswertung gibt Tabelle 1 wieder, die den Beginn der seit Anfang 1925 plötzlich eingetretenen Aenderungen der Horizontalintensität

Tabelle 1.

			h	m	
1925,	April	27	: 14	57.1,	M. G. Z.
	August	22	: 14	47.6,	
1926,	Januar	22	: 15	35.0,	
	Januar	26	: 16	18.0,	
	Februar	23	: 16	25.0,	
	März	5	: 10	4.0,	
	April	14	: 14	1.7,	
	Mai	3	: 21	9.4,	
	Juni	1	: 11	9.6,	

enthält. Bemerkt sei, dass nur die characteristischten Fälle ausgewählt sind, die auch auf der Schnellregistrierung nach einem ruhigen Verlauf einer scharfen Knick, sei es nach zunehmender oder abnehmender Intensität zeigen. Bisher ist die in Potsdam befindliche Schnellregistrierung wohl die einzige ihrer Art, abgesehen von der vielfach gebräuchlichen Eschenhagen'schen Anordnung, die jedoch wegen ihres grossen Papierverbrauchs für einen dauernden Betrieb kaum geeignet ist. Es mögen daher die hier mitgeteilten Daten ihrerseits dazu beitragen, das durch Mitteilung gleichartiger Ergebnisse anderer Observatorien das angeregte Problem einer Bearbeitung unterworfen werden kann.

Die erfolgte Auswertung gab gleichzeitig Anlass, die nunmehr seit 1½ Jahren in Betrieb befindliche Registrierung and ihre Zusatzapparaturen einer Kritik zu unterziehen und die Zuverlässigkeit der Zeitangaben zu prüfen.

[1]C. Chree, *Proc. Phys. Soc.*, v. 38, No. 1, 1925 (35-46).
[2]Ad. Schmidt, *Ber. über die Tätigk. d. Preuss. Met. Inst. im Jahre 1925.*

Die Zeitmarken werden erstens zu jeder vollen Stunde von der Uhr ausgelöst, die auch für die Hauptregistrierung des Zeitkontakts liefert. Ausserdem wird die Zeitmarkenlampe alle zehn Minuten, und zwar um 5^m, 15^m . . . . 55^m, durch eine besondere Uhr eingeschaltet, deren Kontaktvorrichtung aus einem sechsstrahligen Stern besteht, der auf der Achse des Minutenzeigers aufsitzt und mithin sechsmal je Stunde einen an der Peripherie des Zifferblattes befindlichen Kontakt betätigt. Diese an sich ziemlich einfache Anordnung erwies sich als sehr zuverlässig. Häufige Beobachtungen des Aufleuchtens der Signallampe ergaben als zeitliche Distanz der Zeitmarken folgende Grenzwerte:

	m		*m*		*m* *s*		*m* *s*
Zwischen Kontakt	55	und	5	:	10 0	und	9 59
	5	"	15	:	10 5	"	10 3
	15	"	25	:	10 2	"	10 1
	25	"	35	:	10 1	"	9 58
	35	"	45	:	9 59	"	9 58
	45	"	55	:	9 57	"	9 55

Fehler von 1 sec. sind bei dieser Zeitbestimmung sehr leicht möglich, sodass die Schwankungen keineswegs restlos der Kontaktvorrichtung zugeschrieben werden können. Als Abstand des Kontakts sind also, auf zehntel Minuten abgerundet, folgende Zeiten anzunehmen, wobei die zehntel Minuten mit Sicherheit verbürgt werden können:

	m		*m*		
Zwischen	55	und	5	:	10.0 Min.
	5	"	15	:	10.1 "
	15	"	25	:	10.0 "
	25	"	35	:	10.0 "
	35	"	45	:	10.0 "
	45	"	55	:	9.9 "

Die beiden Abweichungen um 0.1 Min. müssten sich auf der Registrierung deutlich bemerkbar machen, da dieser Zeit eine Abscissenlänge von 0.2 mm. entspricht. Jedoch werden sie von dem viel stärker ins Gewicht fallenden unregelmässigen Gang der Registriertrommel überdeckt. Der Sollwert von 20 mm. Papierlänge für 10 Minuten wird nämlich um einen regellos wechselnden Betrag, der 0.5 mm. erreicht, übertroffen oder unterschritten.

Diese Abweichung lediglich linear zwischen zwei Zeitmarken zu verteilen, würde keinen genügenden Ausgleich für die geforderte Genauigkeit einer zehntel Minute schaffen, da die Abweichungen zweier benachbarter Zeitabschnitte, meist infolge entgegengesetzten Vorzeichens, allzu ungleich sind. Eine Ausgleichung unter Berücksichtigung des quadratischen Gliedes ergab auch, dass hierdurch noch Korrektionen, allerdings im Ausnahmefall, bis zu einer zehntel Minute auftreten. Die Auswertung geschah dementsprechend nach folgenden Formeln:

$$t = \frac{a}{c} - \theta$$

$$c = 2 + \frac{\alpha + \beta}{20}$$

$$\theta = \frac{1}{40} \frac{\beta - \alpha}{\beta + \alpha + 40} a^2 \sim \frac{\beta - \alpha}{1600} a^2$$

worin t die zu bestimmende Zeitdistanz gegen die nächstliegende Zeitmarke, a, der Abstand von dieser Zeitmarke in mm, nach zunehmender Zeiten positiv, α und β die Differenzen der Längen der zu beiden Seiten der Zeitmarke liegenden Abschnitte gegen 20 mm, positiv als Ueberschuss negativ als Fehlbetrag, α auf der Seite abnehmender, β auf der zunehmender Zeiten.

Eine weitere Korrektion ergab sich noch durch die gegenseitige Verschiebung der von den beiden Magnetspiegeln erzeugten Bildern. Die beweglichen Spiegel befinden sich nämlich einerseits über, anderseits unter dem festen Spiegel, der das Bild der Zeitmarke and der Basislinie entwirft. Die von ihnen entworfenen Lichtpunkte liegen daher nicht auf einer zu der Basis senkrechten Geraden, sondern sind um 0.5 mm. gegeneinander verschoben. Infolge der symmetrischen Anordnung kann man unbedenklich diese 0.5 mm. bei jeder Kurve zur Hälfte berücksichtigen, also bei der einen 0.12 Minuten zuschlagen, bei der andern dieselbe Zeit in Abzug bringen.

Bei Berücksichtigung aller dieser Fehlerquellen, die zum grössten Teil auf der provisorischen Anordnung beruhen, sich also bei endgültiger Aufstellung meist vermeiden liessen, können die mitgeteilten Zeitangaben (Tabelle 1) mit einer mittleren Unsicherheit von 0.1 min., mit einer maximalen von kaum 0.2 min. bewertet werden.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE APIA OBSERVATORY, APRIL TO JUNE, 1926.

(Latitude, 13° 48′.4 S.; longitude, 171° 46′, or $11^h\ 27^m.1$ W. of Greenwich.)

Greenwich Mean Time			Range		
Beginning		Ending	Decl'n	Hor. Int.	Vert. Int.
1926	h m	d h m	′	γ	γ
Apr. 14	14 00	15 15 ..	9.6	326	Not recorded
May 3	22 50	5 12 ..	4.0	154	18
May 9	21 ..	10 11 ..	4.8	148	14
June 1	11 8	2 12 ..	4.4	195	10

April 14, 1926.—This storm is the largest experienced at this Observatory since May, 1921. A sudden commencement begins on April 14 at $14^h\ 00^m$, Greenwich mean time, the maximum value of H being 35255γ at $14^h\ 17^m$ on April 14 and the minimum value, 34929γ at $7^h\ 28^m$ on April 15. About 15^h on April 15 the curve becomes smoother. April 16 and 17 are both days of character 2, although the ranges on these days are not exceptional because the curve remains low all the time.

May 3, 1926.—There is a sudden deflection upward at the time given as the beginning, but smaller movements have set in about 40 minutes earlier, while the paper was being changed. The end comes gradually, and cannot be timed with precision. On *May 5* there is a small storm.

May 9, 1926.—This storm begins and ends gradually, and in neither case can a precise time be stated.

June 1, 1926.—This storm begins suddenly, with movement about 20γ upward. The time given as the end is that at which the curve becomes distinctly smoother.

The storm in April is the only one in which the range in declination is affected.

ANDREW THOMSON, *Director;* C. J. WESTLAND, *Observer.*

APIA OBSERVATORY, WESTERN SAMOA.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE HUANCAYO MAGNETIC OBSERVATORY FOR APRIL TO JUNE, 1926.

(*Latitude, 12° 02′.7 S.; longitude, 75° 20′.4 W., or 5*^{h} *01*^{m} *W. of Greenwich.*)

April 14, 1926.—A disturbance of considerable intensity began on April 14 at 14^h 02^m, with a sudden commencement. The horizontal intensity increased within six minutes of time by about 110γ. High values of H occurred at intervals until 20^h with large fluctuations; within the next hour the force decreased greatly, the spot going beyond the limits of registration, remaining lost, except for brief periods, until 13^h on April 15. A series of large fluctuations then brought the spot back to the paper, but the value remained low until the following day, when normal conditions were gradually resumed. The sudden commencement of this storm was also shown in the D and Z traces.

May 3, 1926.—A magnetic storm of but moderate intensity but marked by a distinct sudden commencement during the day beginning May 3, at 21^h. At 21^h 14^m on May 3 the horizontal intensity increased by about 42γ, this change occupying but two minutes of time. Leisurely fluctuations of no great amplitude occurred between this hour and 5^h on May 4 and between 13^h and 19^h on the same day. Shortly after this the intensity resumed its normal value.

June 1, 1926.—A disturbance of moderate intensity began with a sudden commencement at 11^h 13^m on June 1. The horizontal intensity increased within three minutes of time by 27γ. After a period of moderate movement covering about three hours, large and rapid fluctuations ensued, continuing until 2.5^h on June 2, when the movements were more leisurely and also decreased in amplitude. The maximum value occurred at 14^h 39^m on June 1, and the minimum (off sheet) shortly before 1^h on June 2.

All times given are Greenwich civil mean time.

RICHARD H. GODDARD, *Observer-in-Charge.*

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON,
HUANCAYO MAGNETIC OBSERVATORY, HUANCAYO, PERU.

NOTE ON MAGNETIC STORMS OF JANUARY 26–27, AND APRIL 14–16, 1926, AT IRKUTSK (ZOUY) OBSERVATORY.

January 26–27, 1926.—Very great fluctuations were noted for horizontal intensity and declination, while for vertical intensity the changes were less violent. The range in horizontal intensity amounted to about 2140γ, and in declination 45′. (Time of beginning not stated in report.)

April 14–16, 1926.—Quiet conditions prevailed in all three elements until at about 13^h 57^m G. M. T., April 14, 1926, there

was an abruptly beginning disturbance, continuing with frequent and large fluctuations. The horizontal intensity reached a maximum of 19339γ at $14^h\ 08^m$ G. M. T., and with widely varying fluctuations decreased to 17,520γ at $7^h\ 01^m$ G. M. T., April 15, a range of 1819γ. Easterly declination varied between extreme values of 0° 19′.85 at $5^h\ 47^m$ and 2° 42.′48 at $12^h\ 57^m.5$, April 15, giving a range of 2° 22′.6, the normal range at this season being 7′ to 10′. Vertical intensity had extreme values of 56132γ and 56594γ at $2^h\ 49^m.5$ and $8^h\ 37^m.5$, respectively, on April 15.

Both of these storms interfered seriously with telegraphic service throughout Siberia, and, as usual, were accompanied by displays of the aurora. The disturbance of April 14–15 was the most severe one recorded at Irkutsk since the installation of the magnetograph in 1906.

(Tracings of magnetograms accompany the report.)

Arnold Pödder, *Chief of the Magnetic Section.*

Meteorological and Magnetic Observatory,
Irkutsk (Zouy).

PRINCIPAL MAGNETIC STORMS RECORDED AT THE CHELTENHAM MAGNETIC OBSERVATORY, APRIL TO JUNE, 1926[1].

(Lat. 38° 44′.0 N.; long., 76° 50′.5, or $5^h\ 07.4^m$ W. of Gr.)

Greenwich Mean Time						Range		
Beginning			Ending			Decl'n	Hor. Int.	Vert. Int.
1926	*h*	*m*	1926	*h*	*m*	′	γ	γ
Apr. 14	14	01	Apr. 17	3	..	70.2	543	698
May 3	21	15	May 6	9	..	32.0	147	111
June 1	11	09	June 2	10	..	58.7	265	362

George Hartnell, *Observer-in-Charge.*

[1]Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

PRINCIPAL MAGNETIC STORMS AND EARTHQUAKES RECORDED AT THE WATHEROO MAGNETIC OBSERVATORY, APRIL TO JUNE, 1926..

(Lat., 30° 19′.1 S.; long., 115° 52′.6 or $7^h\ 44^m$ E. of Gr.)

PRINCIPAL MAGNETIC STORMS.

Greenwich Mean Time						Range		
Beginning			Ending			Decl'n	Hor. Int.	Vert. Int.
1926	*h*	*m*	*d*	*h*	*m*	′	γ	γ
Apr. 14	13	52	16	12	26	32.6	...	...
Apr. 14	13	52	16	12	27	....	...	253
Apr. 14	13	53	16	12	32	....	331	...
June 1	11	10	1	23	43	26.8	213	146

April 14-16, 1926.—Though disturbed generally, the month of April 1926 presents only one storm of any severity, that occuring on April 14-16. This storm began with a relatively mild commencement at $13^h 53^m$, when all the elements increased slightly. At $14^h 02^m$ they changed more abruptly, still increasing, however. A general decline in the value of horizontal intensity followed, and the greatest departure from the mean monthly value occurred at $6^h 50^m$ on April 16; the downward trend was interrupted several times, notably at $20^h 41^m$ on April 14.

Shortly after 20^h, April 14, the traces showed considerable oscillation of small period and amplitude. After 6^h, April 15, both the period of the oscillation became longer and the amplitude larger, with the result that large peaks and bays were formed, this effect being superimposed on the relatively steady change in the values of the elements. A change from disturbed to subnormal conditions occurred at approximately 16^h on April 15.

In its general features this storm strongly resembles the storm of February 23-24, 1926. Though the commencement of this storm was not so sudden, yet the movements following its inception, the general drift in horizontal intensity with its superimposed oscillations, and the large peaks and bays about 20 hours after the beginning of the disturbance were characteristics of both storms. A fine auroral display on the night of April 15 was reported from New Zealand, though no reports of either auroral displays or interference with telegraphic communication were reported from Western Australia.

June 1, 1926.—Although the month of June was disturbed, with the character for the total force of 0.7, the only disturbance of any magnitude was that of June 1. This shows a distinct though mild sudden commencement at $11^h 10^m$ on June 1, wherein horizontal intensity increased 27γ in about five minutes. Both the declination and vertical-intensity traces show a small decrease followed immediately by a similar movement in the opposite direction to practically the original value, the amplitudes of the movement being $1'.1$ and 5γ, respectively.

The storm has no outstanding features. Roughly, it may be divided into three phases. Though the horizontal-intensity trace is disturbed from the onset of the storm, the other elements show no great departure from the average monthly curve until about $14^h.5$. From that time until 21^h all three traces are characterized by large peaks and bays.

In the second phase the slow oscillations of the first phase are somewhat restricted and have superimposed upon them pulsations of much smaller period and magnitude which persist for some 11 hours. During this time the major portion of the decrease in the value of horizontal intensity occurs.

The final stage lasts from 8^h to almost 24^h on June 2 and shows at first a number of large slow movements, with an upward trend in the horizontal-intensity curve, followed by a general recovery of all three elements to more normal conditions.

EARTHQUAKE RECORDS.

Greenwich Mean Time						Range			Remarks
Beginning			Ending			Decl'n	Hor. Int.	Vert. Int.	
1926	*h*	*m*	*d*	*h*	*m*	*mm*	*mm*	*mm*	
Apr. 12	8	43	12	9	02	1.4	...	...	Two phases distinguishable; *D* and *H* traces together and difficult to separate properly.
Apr. 12	8	48	12	9	07	...	1.3	...	
Apr. 12	8	49	12	9	12	...	...	0.9	
June 24	21	22	24	21	34	...	...	...	Two phases distinguishable. Recording drum hung up in middle of second, giving false idea of range. Second phase in *D* commences at $21^h\ 28^m$.
June 24	21	22	24	21	35	1.0	...	...	
June 24	21	25	24	21	37	...	0.8	...	

All times given are Greenwich mean time.

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ÉTUDES SUR LE MAGNÉTISME TERRESTRE, 1877-1924, RÉSUMÉES PAR J. de MOIDREY, S. J.—FASCICULE V.

Un nouveau fascicule vient continuer celui dont compte-rendu a été donné dans le *Journal* l'an dernier, p. 24.

La première Etude de cette fois a été plus particulièrement inspirée par différentes notes qui ont paru dans le *Journal.* C'est une revue détaillée de nos magnétogrammes de 1877 à 1924, au point de vue des marques qui sont dues ou ont pu être dues à des tremblements de terre. Les auteurs ne se sont pas limités au cas des macrosismes ni même à ceux où averti d'abord par les sismographes, l'observateur cherche si les magnétomètres ont aussi été agités. Tous les photogrammes ont été étudiés à la loupe *avant* aucun examen des sismogrammes. Il s'en est suivi une liste contenant des marques dont beaucoup sans doute n'ont rien de sismique. Mais nombre d'autres ont été relevées qui semblent dignes d'attention.

Il y a celles auxquelles ne correspond *rien* sur les sismogrammes et celles qui *précèdent* les indications des sismographes pourtant relativement plus sensibles. Ces deux catégories portent à penser qu'au moins quelquefois les boussoles ont répondu à des appels magnéto-électriques et non aux seuls mouvements mécaniques. Il faut avoir présent à la pensée que les sismographes quelque perfectionnés qu'on les suppose, n'enregistrent que les ébranlements mécaniques, tandis que les boussoles sont sensibles aux uns et aux autres.

Le fait des courants électriques aurait à être approfondi et précisé, en tenant compte de la distance des épicentres, car il y en a de fort lointains et presque jusqu' aux antipodes. Le temps a manqué pour mener ceci à terme.

Une autre particularité a été assez souvent relevée. Les planches I et II en fournissent plusieurs exemples indiscutables—3 juin 1890, 19 mars et 1er décembre 1921, 3 septembre 1922, etc. C'est qu'au moment d'un séisme le champ magnétique a été manifestement modifié, le plus souvent augmenté. Ceci ne s'explique guère que par un courant électrique. Ce courant a dû, à mon sens, être produit à l'épicentre. Il n'est pas facile de concevoir qu'une secousse produite par exemple aux Kouriles, en Islande, en Crète ou au Chili ait ébranlé les couches terrestres en Chine assez vivement pour que leur frottement ait augumenté *ici* le champ magnétique d'une manière notable. Au moins en faudrait-il une bonne preuve. Ceci paraît plus évident si, comme le 1er mai 1915, les enregistreurs sismiques ne parlent que 5 minutes plus tard.

Les Etudes suivantes sur les jours calmes et les jours troublés, sur les débuts brusques, etc., ont été conduites de manière à ne pas exiger une connaissance très précise de l'heure. On voulait utiliser des documents remontant à une époque où personne ne songeait aux fractions de minute. L'allure des jours calmes et troublés, mois par mois, ne demanderait pas plus d'exactitude. Celle des perturbations à début brusque est bien ce qu'on pensait, mais le grand nombre (17) de groupements effectués lui donne ici du relief.

L'Etude 28, simple note sur le temps de Greenwich, sans amoindrir l'utilité d'un temps international, ferait craindre que, dans son emploi universel, il n'y ait parfois plus d' engouement qu'il ne faudrait.

Lu-kia-pang, Chine. J. DE MOIDREY, S. J.

PROVISIONAL SUNSPOT NUMBERS FOR JUNE TO AUGUST, 1926.

Day	Jun.	Jul.	Aug.	Day	Jun.	Jul.	Aug.
1	62	104	76	17	48	10	40
2	73	76	62	18	52	0	40
3	45?	74	89	19	50	14	51
4	..	64	101	20	52	22	53
5	80	43	82	21	44	41	74
6	..	46	79	22	37	49	58
7	95	..	..	23	52	55	64
8	86	..	50	24	55	99	78
9	92	23	67	25	..	..	73
10	88	23	62	26	86	125	62
11	94	28	..	27	88	..	55
12	62	16	70	28	99	115	55
13	75	7	75	29	106	..	55
14	80	11	55	30	109	91	49
15	57	13	47	31		100	43
16	65	8	45				
				Mean for month	71.6	48.3	62.4

Zürich, Switzerland. A. WOLFER.

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Terrestrial Magnetism and Atmospheric Electricity

VOLUME 31 DECEMBER, 1926 No. 4

DETERMINATION OF THE ATMOSPHERIC POTENTIAL-GRADIENT REDUCTION-FACTOR AT THE WATHEROO MAGNETIC OBSERVATORY, WESTERN AUSTRALIA.[1]

BY H. F. JOHNSTON.

Observations of atmospheric potential-gradient have been made at divers places over the Earth's surface during the last half century at least. These observations are obtained by measuring the potential at some atmospheric point by means of a collector. Various types of collectors have been used such as jets of water or flame, and radio-active material. The potentials of the collectors are determined by means of electroscopes or electrometers either by eye readings or by some form of continuously recording apparatus.

Large quantities of data are in existence. It is, however, much to be regretted that nearly all of these values are relative and not absolute. The standard for reference at any place is the atmospheric potential at a point one meter above the surface on a level plain. The point must be undisturbed by the presence of any obstruction such as grass or low shrubs for a distance of twenty-five feet and with no object such as a tree or building closer than ten times its height.

In making a long series of continuously recorded observations, it would be most difficult to even approximate these conditions. In fact observations are usually taken by mounting the collector outside a building and measuring its potential by means of an electrometer inside the building. Rarely is one so fortunate in placing the collector outside the building at such a point that the potentials recorded are exactly the same as the absolute values which would be obtained at an undisturbed point one meter above the surface in the immediate vicinity.

In such a case where the observed values and the absolute values differ it is necessary to multiply each of the observed values by a factor to reduce them to absolute values of atmospheric potential-gradient in volts per meter. This factor is called the "reduction-factor" and it is the purpose of this paper to give a summary of the determinations of the reduction-factor made at

[1]Presented August 26, 1926, before Section A (astronomy, mathematics, and physics) at the Perth meeting of the Australasian Association for the Advancement of Science.

the Watheroo Magnetic Observatory during the last 16 months, with some hints as to the precautions which are necessary for the proper determination of the factor.

At the Watheroo Magnetic Observatory the values of atmospheric potential-gradient are continuously recorded at a point outside a building specially set aside for atmospheric-electric observations. The collector is a brass disc one inch in diameter covered with a small quantity of ionium. The ionium itself is protected from the elements by a thin layer of bakelite which is baked on. The disc is three feet, 4 inches (3′4″) from the wall of the building and 8 feet above the ground-level. To ensure that the whole surface of the atmospheric building is always at ground potential the whole building is completely covered with 16-mesh copper screening. The collector is connected by means of a carefully insulated rod to a recording bifilar electrometer which gives a continuous photographic record of the potential of the collector.

The standardizing station for determining absolute values has been established at a point 1/6 mile distant, on a level stretch of sand plain. All vegetation has been removed from an area ten meters in diameter and nothing but very low shrubs have been allowed to remain within a distance of 20 meters from the observation spot. Fig. 1 gives the general location of the standardizing station and the atmospheric-electric building in the south-west corner of the government reserve for magnetic purposes. Fig. 2 gives a cross-section of the atmospheric-electric building in a plane through the ionium collector and the potential-gradient recording apparatus.

The method of obtaining absolute values of potential gradient is briefly as follows. At the standardizing station we have erected two posts 20 meters apart and 1.1 meters in height. An insulated wire is stretched between these posts and an ionium collector is attached to the mid-point of the wire. The tension of the wire is adjusted, by means of a turn-buckle, until the height of the collector is exactly one meter above the surface. The insulated wire is attached to the electrometer by means of a fine copper wire and the electrometer is placed in a low shelter 1.3 meters high which is placed four meters beyond, and one meter to one side of the line joining the two posts. The insulation of the stretched wire is maintained by sulphur insulators which are one inch in diameter and have a removable cap to protect against moisture and insects over the exposed sulphur surface. The sulphur surface is scraped once every hour while observations are in progress. A general diagram of the set up is given in Fig. 3.

The general method of observation is to take simultaneous observations at both the standardizing station and in the atmospheric-electric building. The potential is read at one-minute intervals and the observations extend over periods of twenty minutes. Six twenty-minute sets are taken for a determination of the value of the reduction-factor. We have found that this is the minimum

number of sets which will give consistent values and these sets should preferably be taken three in the forenoon and three in the afternoon. The reduction-factor observations are made once monthly at Watheroo on a selected day during the month when it is considered that the best conditions are likely to exist.

Table 1 gives the actual observed values of three twenty-minute sets taken at three consecutive standardizations on August 4, August 31, and September 18, 1925. These sets, which are representative ones of the six sets taken on each of those days, were chosen because the times of observations happened to be the same for all three days, namely, from 14^h05^m to 14^h25^m, 120° M.T., E. of Gr. Each set has been tabulated in three columns, the first gives the potential gradient in volts per meter as observed at the field station, and the second the simultaneously observed values of potential in the atmospheric-electric building, the third gives the ratio of these two values, i.e., the reduction-factor. It will be noted

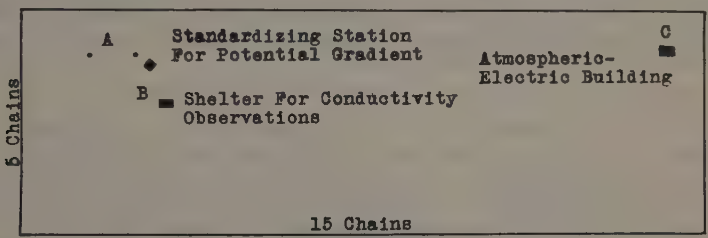


Fig. 1

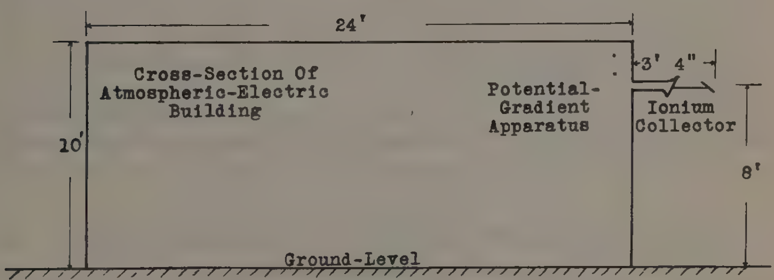


Fig. 2

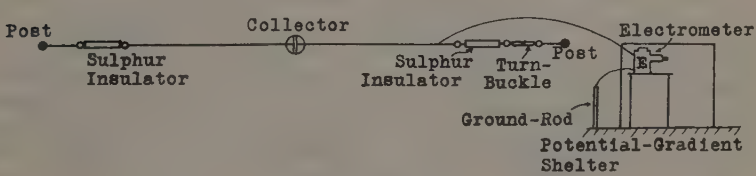


Fig. 3

that these ratios show a considerable range for any one set. The extreme values for each set differ by 0.54, 0.30, and 0.32, respectively, which in percentages of the average value of the reduction-factor are 50, 28, and 30. The range in the value of the reduction-factor for the first set was 50 per cent and is greater than the other sets and is due to the fact that there were clouds during the first set and it was cloudless for the second and third sets. This is easily accounted for since there are very rapid and large fluctuations of the potential gradient on a cloudy day, and though the observations were strictly simultaneous as regards time yet they were not simultaneous as regards potential-gradient conditions.

Table 1.—*Observed values of atmospheric-potential gradient.*

(Representative 20-minute sets of observations for the determination of the reduction-factor. Column *A*: Potential gradient in volts per meter as observed at the field station. Column *B:* The potential gradient as observed with the potential-gradient apparatus in the atmospheric-electric building. Column *C*· Factor to reduce the values given by the potential-gradient apparatus to volts per meter.)

120 M. T. East	August 4			August 31			September 18		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
h m	*volts*	*volts*		*volts*	*volts*		*volts*	*volts*	
14 05	116	83	1.40	65	60	1.08	70	78	0.90
06	69	69	1.00	69	63	1.10	92	81	1.14
07	72	72	1.00	88	74	1.19	69	72	0.96
08	77	70	1.10	68	76	0.89	66	62	1.06
09	71	58	1.22	77	84	0.92	63	65	0.97
10	93	77	1.21	99	91	1.09	72	62	1.16
11	113	101	1.12	93	81	1.15	68	63	1.08
12	73	85	0.86	102	90	1.13	81	75	1.08
13	75	83	0.90	79	88	0.90	71	66	1.11
14	94	84	1.12	85	80	1.06	81	73	1.01
15	91	70	1.30	84	78	1.08	70	69	1.08
16	81	81	1.00	83	70	1.19	62	62	1.05
17	107	99	1.08	78	70	1.11	62	59	1.02
18	86	93	0.92	102	96	1.06	58	57	1.22
19	74	80	0.92	82	88	0.93	83	68	1.03
20	86	72	1.19	85	74	1.15	64	62	0.99
21	99	72	1.38	74	69	1.07	75	76	1.09
22	89	76	1.17	72	68	1.06	82	75	1.19
23	86	71	1.21	66	63	1.05	88	74	1.05
24	72	63	1.14	75	69	1.09	83	79	1.05
25	78	69	1.13	63	69	0.91	87	84	1.04
Mean	85.8	77.5	1.11	80.0	76.2	1.06	73.9	69.6	1.06
Extreme values of *C*	0.86 to 1.40			0.89 to 1.19			0.90 to 1.22		
Range in *C*	0.54			0.30			0.32		
Clouds	9, A-Cu, Fr-A-Cu			Cloudless			Cloudless		
Wind	Gusty			Strong			Light		

In Table 2 is shown a summary of the average values of the six sets of determinations on each of the days. The daily average factors obtained by taking a mean of all observations on any one day show an agreement within two per cent. The values for the six sets for any one day show an agreement among themselves within approximately five per cent.

TABLE 2.—*Average potential-gradient reduction-factors.*

(Each set consists of 21 observations taken at one-minute intervals over a period of 20 minutes.)

Date 1925	Average potential-gradient factor for set number						Average daily factor
	1	2	3	4	5	6	
August 4	1.12	1.11	1.10	1.09	1.11	1.09	1.10
August 31	1.10	1.06	1.11	1.06	1.09	1.11	1.09
September 18	1.08	1.05	1.11	1.06	1.09	1.07	1.08

To further bring out the lack of agreement on cloudy days Table 3 was prepared and in it are tabulated the extreme ranges in the individual factors for each set. On the day when there were clouds the average daily range was 50 per cent and on the two cloudless days 28 and 35 per cent. The other two days were cloudless and the only other condition which was different was the wind velocity. This led us to examine other sets of reduction-factors made at different times, and from the examination we were able to conclude that on days when the wind was light the average daily value of the extreme range was always greater. Here again the stagnant atmospheric conditions might make the time simultaneity of the observations not the only factor necessary to be observed in getting strict simultaneity of potential-gradient conditions.

TABLE 3.—*Extreme ranges in the individual reduction-factors.*

(Each set consists of 21 determinations.)

Date 1925	Extreme ranges in individual factors for set number						Average daily range
	1	2	3	4	5	6	
August 4	0.52	0.62	0.56	0.50	0.55	0.47	0.54
August 31	0.29	0.39	0.20	0.31	0.26	0.37	0.30
September 18	0.40	0.46	0.43	0.32	0.26	0.36	0.37

The summary of the meteorological conditions in regard to amount of cloud and strength of wind is shown in Table 4.

TABLE 4.—*Amount of cloud during the twenty-minute periods and the average daily wind.*

Date 1925	Amount of cloud for set number						Average daily wind
	1	2	3	4	5	6	
August 4	0	1	1	3	8	10	gusty
August 31	0	0	0	0	0	0	strong
September 18	0	0	0	0	0	0	moderate

On April 24, 1925, we removed a wireless mast, which was 30 feet high and situated 70 feet from the atmospheric building. The reduction-factor, which had been 1.21 prior to the removal of the mast, was consequently changed and a new series of observations was begun. Table 5 gives a summary of all of the determinations of the reduction-factor made since that time. The average of all the determinations is 1.07 and the extreme values are 1.02 and 1.10, an extreme range of 8 per cent. The series taken in 1925 show larger ranges that those in 1926 due in all probability to a slight change at the standardizing station. In November, Mr. W. J. Rooney began a resistivity-survey of the region at the Watheroo Magnetic Observatory. The resistivity of the surface layer of sand at the standardizing station was found to be 1.5 megohms per cm.^{3} Prior to these observations the electrometer "ground" had been to an iron post driven into the sand at the shelter. In view of the very high resistivity of the surface layer, a circle of clay of resistivity 20 ohms per cm^3 was placed beneath the ionium collector and the electrometer was grounded to this clay. Subsequent to this there has been slightly better agreement in the average values of the reduction-factors.

Figure 4 has been prepared to show the values minute by minute of the potential gradient observed at the field station and at the atmospheric-electric building. The curve for the observations in the building is much smoother than the one outside due to the fact that the capacity of the system in the building is of the order of 100 cms, while the capacity of the apparatus at the field station is approximately one-tenth of that amount. This accounts for a part of the differences in the values of the individual factors. It is considered advisable that in order to eliminate this effect one should increase the number of observations rather than to increase artificially the capacity of the field apparatus by means of a condenser.

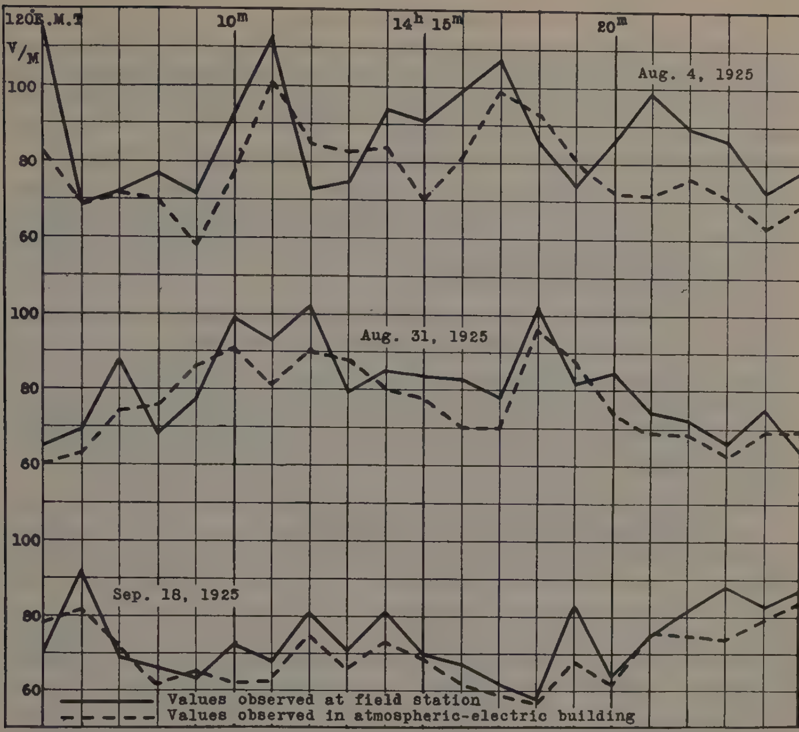


Fig. 4.—Comparison of simultaneous observations at field and observatory stations.

TABLE 5.—*Summary of determinations of potential-gradient reduction-factors.* (Each day's value depends on the average of 120 values observed during six twenty-minute intervals.)

Date	Factor	Date	Factor
1925		1926	
April 24	1.04	January 21	1.05
May 4	1.09	January 22	1.06
May 9	1.06	February 9	1.07
May 11	1.03	March 1	1.07
June 10	1.07	April 29	1.10
July 3	1.08	June 7	1.10
August 4	1.10	July 13	1.08
August 31	1.09	August 3	1.09
September 18	1.08		
November 17	1.05		
December 11	1.02		

Average of all determinations, April 1925—August 1926: 1.07.

Summary.

At the Watheroo Magnetic Observatory it has been found that in order to determine the value of the "reduction-factor" by which it is necessary to multiply the values obtained by the potential-gradient apparatus in order to reduce them to volts per meter over level ground to the best possible accuracy:

(1). A determination should consist of not less than six simultaneous sets of 20 minutes each spaced throughout a day;

(2). The standardizing station should be as close as possible to the observing station;

(3). The observations should be taken only on a cloudless day with a wind of at least 10 miles an hour;

(4). Electrically-disturbing objects such as trees, poles, or buildings, should be as far away as possible, and the outside of the observing building grounded by a metallic screen.

WATHEROO MAGNETIC OBSERVATORY, WESTERN AUSTRALIA,
CARNEGIE INSTITUTION OF WASHINGTON,
August 18, 1926.

A VERTICAL-INTENSITY MAGNETOMETER.

By D. la Cour.

Magnetic observations, and in particular those necessary for the control of magnetograph records, at stations in high magnetic latitudes have been greatly handicapped, because of unfavorable magnetic conditions as well as temperature conditions at such stations, for lack of a suitable instrument to determine rapidly and with precision the vertical intensity of the Earth's magnetic field. The establishment of the Godhavn Magnetic Observatory in Greenland, where the magnetic inclination is about 82°, led the author to consider electrical methods of determining the magnetic vertical-intensity of the Earth's field. An experimental apparatus was used during a trip to Greenland in 1925 to select a site for the Observatory, and as a result of these experiments a new type of vertical-intensity magnetometer was developed and was sent in August 1926, after trial at the Rude Skov and Potsdam observatories, to the Godhavn Observatory for use there regularly.

The essential part of the new instrument is a precise standard for mutual inductance, that is, an inductor with two sets of windings, and very strongly built. By rotating the standard 180° on a horizontal axis the vertical intensity of the Earth's magnetic field gives rise to electromotive forces in the windings. One winding is connected with a ballistic galvanometer which, through the arrangement described below, measures the induced effect; the sensitivity of the galvanometer is such that rotating the inductor 180° would cause a deflection quite beyond the scale-limit of the galvanometer, for example, at Rude Skov for a scale-distance of 2 meters, a deflection of 10 meters. This arrangement, a sort of zero-method, by which the deflection of the galvanometer never exceeds a few centimeters even for highest sensitivity of the apparatus, utilizes an accurately determined electric current which, during the turning of the inductor, may be made or broken in the second winding. The making or breaking in this current through the second winding induces an electromotive force in the winding connected with the galvanometer, and the connections are such that the electromotive force induced by the variation of the "compensating current" is opposite to the electromotive force induced by the vertical component of the Earth's magnetic field during a turn of the inductor. Thus the resulting deflection of the galvanometer corresponds to the difference of the two induced electromotive forces. By again turning the coil and using some other compensating current, a second galvanometer reading is obtained. By means of two such readings the strength of a compensating current, which should give just the zero-deflection of the galvanometer, is readily computed.

This "zero-current" must be of such strength that when in circuit it induces twice as many lines of magnetic force through the coil connected with the ballistic galvanometer as the vertical component of the Earth's field does when that coil is in a horizontal position. In that case namely the last mentioned coil encompasses the same number of lines of magnetic force before and after the turning.

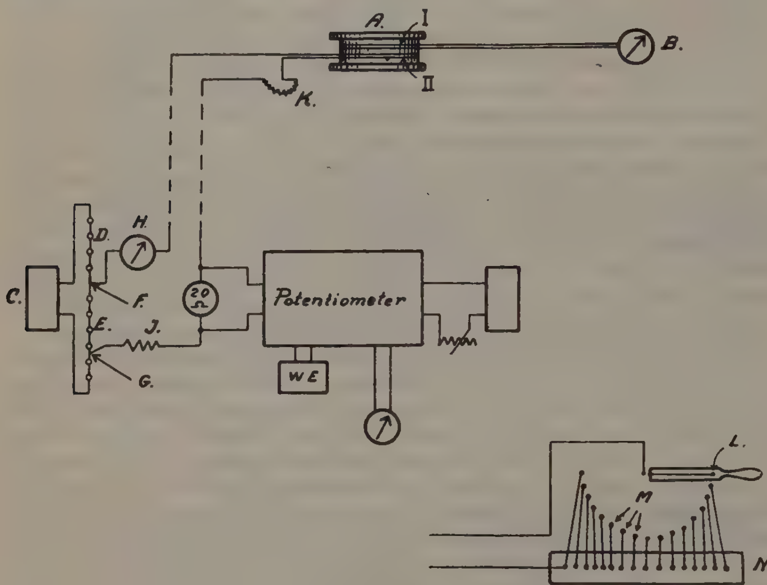


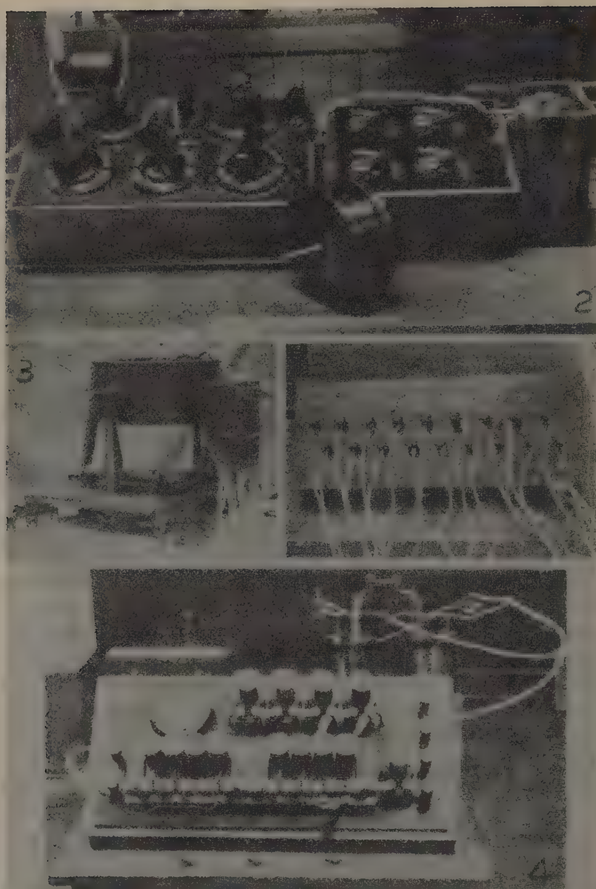
FIG. 1.

Figure 1 shows some of the details diagrammatically. A is the precise standard for mutual inductance with its two windings I and II. Winding I is connected directly with a sensitive Broca galvanometer, B, adjusted for ballistic work. From a 2-volt storage battery, C, a current of about 0.15 ampere is passed through the resistances D and E. The resistance-steps in D are 0.1, 0.2, 0.3, and 0.4 ohm, while the resistance at E may be varied from 1 to 20 ohms. The compensating current is taken from the points F and G. From G the current passes a resistance J (about 40 ohms) and then a standard resistance of 20 ohms, from which the current is measured by a precise and well-adjusted potentiometer of 20,000 ohms giving readings directly to 0.0000005 ampere (corresponding approximately to 1γ). From the 20-ohm standard resistance the compensating current passes a system of resistances at K, through the horizontal axis to the winding II of the precise standard for mutual inductance, and through a Weston milliammeter, H, to the point F of the primary circuit.

The resistance at K serves to control automatically the increase or decrease of the current in winding II. If this circuit be closed or broken suddenly in comparison with the time required to turn A, the galvanometer B would be very irregularly affected and some difficulties in observing the real difference of the two impulses would arise. Therefore, the making and breaking of the current is done by a contact-arm L rigidly connected with the marble spool of A. During each turn of the inductor the contact-arm L is moved over a series of buttons, M, each of which is connected with a pole of a specially constructed resistance-box, N. This box contains a number of resistances in series and is so adjusted that for each 10°, as A is turned, the compensating current through winding II is increased or diminished by such an amount that the inductance in winding I caused by the alteration of the current in winding II nearly compensates the inductance in winding I caused by the alteration in the number of lines of force of the Earth's field corresponding to the turning of the inductor through the same 10°. Thus, at 18 times during each 180° turn of A the effect of inductance by the Earth's magnetism in winding I is very nearly compensated by the inductance from the alteration of the compensating current through winding II. As may be easily seen from the diagram, the constancy of the measurements depends much upon the standard resistance used for shunting the potentiometer. There seems to be no simpler way to control this essential point than to increase the subdivision and range of standard resistance units in N. It is understood that before using the Weston standard cell it must be kept at a constant temperature during some hours.

As to the inductor used, I wish to mention some details regarding this prominent part of the whole instrument which is shown with attached thermometer in the foreground of Figure 2. Generally such coils are wound on marble, which not only gives strength but the added good quality of being unchanged with time. It is especially to be noted that in winding the wire the tension is so great that alterations of the dimensions of the windings depend only on the temperature-coefficient of the marble. The effect of a temperature-change on the inductor increases for rising temperature the mutual inductance between its two windings proportionally to the temperature, while the area of the windings increases with the square of the temperature. Thus, the influence of temperature on the coil may be considered as well defined and well known.

The coils used are the ordinary 0.01-henry standards. However, the values of inductance and also the area which the coils represent are of no significance. It is only the *immutability* of the coils which is important, besides, of course, the mutual inductance between the two sets of windings. While all my standards have an inductance near 0.01 henry, the area of the windings differs astonishingly, namely, by 5 per cent and more. The order of magnitude of the area of the coils is about 28,000 cm^2. Each winding has a resistance of about 3.6 ohms. On account of the rigid form and



Figs. 2, 3, 4, and 5.

durability of the coils, they are quite suitable for transportation between magnetic observatories for purposes of comparison.

Two different types of the Broca galvanometer have been used in the experimental work, namely, that manufactured by the Cambridge Instrument Company and by Carpentier. I prefer the type made by Carpentier, especially because its controlling magnet is much smaller and may be much more easily adjusted than that of the Cambridge type. After some practice, the observer may use the galvanometer very well for ballistic work even if the time for one oscillation is as short as 3 seconds because of the small deflections necessary. The beginner encounters difficulties in using a galvanometer with such a high sensitivity, especially on

account of thermo-electric effects, etc. By covering all connections and the poles of winding I of the inductor with some heat-insulating material, it is possible, however, to reduce such temperature-effects so much that the "zero-point" of the galvanometer may be quite satisfactorily read before each turning of the inductor.

The apparatus for turning the inductor *A* is shown in Figure 3. It consists of a cast-bronze container, one side being open for the introduction of *A*. The inductor has on the bottom three bearings of caouthouc and, when inside the container, it may be fastened by a ring screwed to the marble; thus, the position of the coil in the container may be adjusted by altering pressure on the rubber bearings. The bronze container has two cast axle supports (not seen on the figure) for its mounting on two pillow-blocks, and a level is provided for adjusting the axle to the horizontal position. Two other levels are mounted on the slate base of the apparatus. The rotation of the container is limited to exactly 180° by two bronze pillars mounted on the slate base and an adjustable contact.

The wires from the four poles of the inductor are led through the axle, thus keeping their position unaltered when it is turned. The wires from winding I go directly to the ballistic galvanometer, while the wires from winding II are connected as shown in Figure 1. The contacts fastened to a vertical slab of slate for the special resistance-boxes are seen in Figure 3. The use of the instrument will be facilitated if the resistance at the sliding contact is always the same, especially when resting on the contact corresponding to "no resistance." The best way to obtain a constant resistance at the contacts seems to be to make them of silver; when clean, experience has shown that silver contacts operate quite satisfactorily.

The true position of the plane of the windings is of minor importance in so far as the measuring of vertical intensity in high magnetic latitudes is concerned. The axis of rotation being nearly parallel to the lines of horizontal intensity the most important adjustment is leveling of the horizontal position of the axis of rotation, and in the neighborhood of the magnetic pole of the Earth even exact leveling is not necessary. It is, however, possible to adjust the position of the windings of the coil for level by sending a current through the windings and examining with a small magnet the resulting magnetic field. A new apparatus for the Rude Skov Observatory to determine *H* as well as *Z* will be ready by the end of 1926.

The potentiometer used for the measurements of the current through winding II is of the type made by Wolff of Berlin and is seen in Figure 2. Each of the 93 resistances of the potentiometer, varying from 0.1 to 1,000 ohms, has been tested separately and in series at the Reichsanstalt in Germany. The potentiometer seems to be a very good one; its internal resistance is nominally 20,000

ohms (20,001 ohms at 18°.5C, the temperature-coefficients being $\alpha = +34.0 \times 10^{-6}$ and $\beta = -0.5 \times 10^{-6}$). At Rude Skov the galvanometer for the potentiometer-current had a sensitivity such that 0.1 ohm would deflect the galvanometer about 5 mm.

Besides the potentiometer, Figure 2 also shows the original Weston standard cell, a storage battery for delivering the constant potentiometer-current, and a resistance-box for adjusting the potentiometer-current corresponding with the electromotive force of the Weston cell. Several of these cells are being taken to Godhavn; one (No. 6205) of the original type is to serve as a standard, while the other cells of a cheaper type are to serve for daily use.

Concerning the resistance-box for adjusting the potentiometer-current, a simpler and cheaper box might have been sufficient. A precise resistance-box rather than a simpler one was supplied the Observatory as it is desired to have at Godhavn an instrument which may be useful for other purposes. It should be mentioned that for electric measurements of the precision needed for the magnetometer the ordinary slide-resistances commonly used for the adjustment of potentiometer-currents can not be recommended.

In Figure 4 is shown the system of resistances in the primary circuit. The four resistances at the left, 0.1, 0.2, 0.3, and 0.4 ohm, serve as resistance D in Figure 1. On line with these, but further to the right, are five resistances of 1, 2, 3, 4, and 10 ohms, respectively (E in Fig. 1). Behind these there are four resistances of 10 ohms each (J in Fig. 1), and, at the upper left-hand, the Weston ammeter (H in Fig. 1). Figure 4 also shows in the background the storage battery (C in Fig. 1) for delivering the primary current, and the two 10-ohm standard resistances connected with the potentiometer.

Figure 5 shows the special resistance-box (N in Fig. 1) containing the 17 resistances permitting the increase or decrease of the current through winding II corresponding to the turning of winding I in the field of the Earth's magnetism. The resistances, all in series, are 0.5, 1.5, 2.5, 4.0, 5.0, 7.5, 10.0, 13.0, 18.5, 25, 40, 60, 100, 185, 400, 1,100, and 6,200 ohms, giving successive totals of 0.5, 2.0, 4.5, 8.5, 13.5, 21.0, 31, 44, 62.5, 87.5, . . . ohms, the calculation of which is based upon the altering of the horizontal projection of the area of winding I during the successive movements of 10°. Instead of making or breaking a current of the intensity i ampere in winding II, it is possible also to compensate the inductance caused by the Earth's field by a current of the intensity $i/2$ by reversing the direction of the current during the turning of the coil. Such a device has some advantages because of symmetry and of a more uniform action of the storage battery and heating of the wire. On the other hand, the original arrangement has some advantages including a simpler construction of the commutator of the turning apparatus, the certainty of obtaining the zero-current, and negligible effect of the warming of the wires by the current. The chief advantage perhaps for the method of re-

versing the compensating current instead of breaking of the double current would be the more uniform action of the storage battery, permitting the use of accumulators of a smaller type than desirable when the make-and-break method is used.

Knowing in advance the approximate current required in winding II for compensating by inductance the effect of a turn of 180° of winding I in the Earth's magnetic field, this current may be established roughly by the use of the Weston milliammeter and suitable selection from the resistances E through G. If, for example, the compensating current should be for a total resistance at D of 0.8 ohm, then the apparatus would be "overcompensated" if the total resistance at D were 0.6 ohm and "undercompensated" if it were 1.0 ohm. Then a measurement may be made in the following way: Arrange for $\Sigma D = 1.0$ ohm and measure the current (i_1) through winding II by the potentiometer, turn A and observe the deflection (α_1) of the ballistic galvanometer B; repeat reading for check. Arrange for $\Sigma D = 0.6$ ohm, measure the current i_2 with the potentiometer, turn A again and read the deflection α_2 of the galvanometer. Read the temperatures of the Weston standard cell, of the standard resistance, and of inductor A (by means of the small thermometer in a bore in the axis of the marble). Make vertical-intensity variometer readings, Z and $Z' = Z(1+\partial)$, at the times when the two 180° turns of A were made

The quantity of electricity, q', sent through the galvanometer B upon the first turn of winding I is $q' = 10^{-8} \cdot Z \cdot 2a \cdot r_1^{-1}$, where a is the area of winding I and r_1 is the total resistance in winding I including the conducting wire and the galvanometer. The making or breaking of the current i_1 in winding II would send through the galvanometer B a quantity of electricity $q'' = i_1 \cdot m \cdot r_1^{-1}$, where m is the inductance of A and r_1 is the same resistance as in the above given expression for q' because the quantity of electricity q'' passes through winding I and the galvanometer B at the same time as the quantity q'. The first reading of the galvanometer then corresponds to the formula

$$C_1\alpha_1 = 10^{-8} \cdot Z \cdot 2a \cdot r_1^{-1} - i_1 \cdot m \cdot r_1^{-1} \tag{1}$$

where C_1 is a constant depending on the sensitivity of the galvanometer, etc. The second turn of A gives

$$C_2\alpha_2 = 10^{-8} \cdot Z(1+\partial) \cdot 2a \cdot r_2^{-1} - i_2 \cdot m \cdot r_2^{-1} \tag{2}$$

If the two turns are made within a short interval of time, we have $C_1 = C_2$ and $r_1 = r_2$, whence

$$\alpha_1[10^{-8} . Z(1+\partial) \cdot 2a - i_2 m] = \alpha_2[10^{-8} \cdot Z \cdot 2a - i_1 m] \tag{3}$$

and in absolute units

$$Z = [\alpha_1 i_2 - \alpha_2 i_1]\ [\alpha_1(1+\partial) - \alpha_2]^{-1}\ [m\ 10^8/2a] \tag{4}$$

Suppose i_0 to be the strength of the compensating current giving zero-deflection of the galvanometer, then

$$10^{-8}\cdot Z\cdot 2a=i_0 m \text{ or } i_0=10^{-8}\cdot Z\cdot 2a\cdot m^{-1}=[\alpha_1 i_2-\alpha_2 i_1]\,[\alpha_1(1+\partial)-\alpha_2]^{-1} \quad (5)$$

Whence

$$Z=i_0(m\cdot 10^8/2a)=i_0\cdot K \quad (6)$$

in which K is the "constant of the coil. K includes only m, the mutual-induction coefficient of the coil, and a, the area of winding I; it varies with temperature.

To investigate the effect of temperature, some measurements were made at Rude Skov between 12° and 26° Centigrade, the results of which are shown graphically in Figure 6. The relation

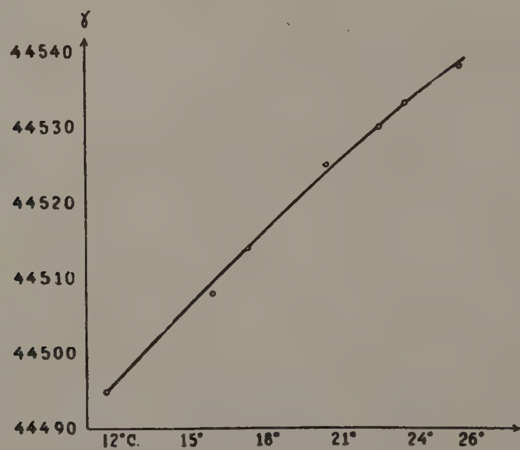


FIG. 6.

found agrees satisfactorily with the temperature-coefficients given by the Reichsanstalt for the standard resistances and potentiometer used as combined with the coefficient of the Weston standard cell and with that of the precise standard for mutual inductance which was determined by the electric method by Dr. Olsen, now in charge of the Godhavn Magnetic Observatory.

Formula (5), in which i_0 corresponds to Z at the time for turn of the inductor giving the deflection α_1, does not clearly show the influence of the variation of Z during the measurement. The formula

$$i_0=[(\alpha_1 i_2-\alpha_2 i_1)\,(\alpha_1-\alpha_2)^{-1}]\,[1-(\partial/2)\,(\alpha_1+\alpha_2)\,(\alpha_1-\alpha_2)^{-1}] \quad (7)$$

where i_0 very nearly corresponds to $Z\,(1+\partial/2)$, shows this influence better. When $\partial=0$ or α_1 is nearly equal to $-\alpha_2$, the formula becomes

$$i_0=i_1+\alpha_1(i_2-i_1)\,(\alpha_1-\alpha_2)^{-1} \quad (8)$$

The condition α_1 being nearly equal to $-\alpha_2$ may easily be secured by means of a resistance-wire shunting one of the resistances in the primary circuit.

TABLE 1.—*Results of Observations with Precise Standards for Mutual Inductance.* (Series A at Potsdam, July 7, 1926, standard No. 2095527; series B at Rude Skov, July 19, 1926, standard No. 2095530.)

Series	G.M.T.	Observed		Computed zero-current, i_0	Obs'd Z ordinate	Corr'n i_0 to Z_b, $n(Z-Z_b)$[1]	i_0 for Z_b	Departures from mean	
		Current, i_1 i_2	Defl'n, α_1 α_2						
	h m	*amp*	*cm*	*amp*	*mm*	*amp*/10^7	*amp*	*amp*/10^7	γ
A	17 19	.0245429	2.97	.0242454	108.1	−16	.0242438	+27	+4.7
	17 21	.0239019	−3.43						
	17 36	.0239007	−3.42	.0242422	108.7	−25	.0242397	−14	−2.5
	17 40	.0245407	2.99						
	17 44	.0246837	4.37	.0242432	108.4	−21	.0242411	0	0
	17 49	.0237404	−4.99						
	18 10	.0237390	−4.97	.0242387	106.4	+ 9	.0242396	−15	−2.6
	18 14	.0246780	4.37						
	18 19	.0246768	4.38	.0242383	105.2	+27	.0242410	− 1	−0.2
	18 23	.0237368	−5.01						
	18 42	.0237348	−5.04	.0242407	106.1	+13	.0242420	+ 9	+1.6
	18 46	.0246743	4.32						
	18 50	.0246733	4.28	.0242389	105.9	+16	.0242405	− 6	−1.0
	18 55	.0237325	−4.99						
B	15 23	.0233444	−5.44	.0236381	17.1	− 4	.0236765	+ 7	+1.3
	15 33	.0239744	6.23						
	15 36	.0239743	6.20	.0236369	17.05	− 2	.0236755	− 3	−0.6
	15 42	.0233418	−5.42						
	15 46	.0233422	−5.43	.0236367	17.1	− 4	.0236751	− 7	−1.3
	15 53	.0239727	6.20						
	16 02	.0239703	6.15	.0236370	17.4	−14	.0236744	−14	−2.6
	16 11	.0233390	−5.50						
	16 16	.0233395	−5.49	.0236375	17.1	− 4	.0236759	+ 1	+0.2
	16 21	.0239702	6.13						
	16 25	.0239688	6.05	.0236402	17.4	−14	.0236776	+18	+3.4
	16 31	.0233360	−5.60						
	16 35	.0233361	−5.59	.0236388	17.5	−18	.0236758	0	0
	16 40	.0239658	6.04						

[1]The factor n, which involves vertical-intensity scale-value and reduction-factor from intensity units to amperes, and Z_b, the arbitrarily taken base-reference for the vertical-intensity records, are 14.8 and 36.0 and 107.0 mm. and 17.0 mm. for Potsdam and Rude Skov, respectively.

Table 1 shows the first series, A, of seven determinations at Potsdam and also another series, B, also of seven determinations at Rude Skov, both in July 1926. The second column gives the Greenwich mean times of observation and the third column the observed currents through winding II before or after each turn. The fourth column indicates the deflections of the ballistic galvanom-

eter corresponding to the differences $(m \cdot i \cdot r^{-1} - 10^{-8} \cdot Z \cdot 2a \cdot r^{-1})$. The zero-currents computed from the deflections, α_1 and α_2, and the respective currents, i_1 and i_2, are given in the fifth column. For purposes of comparison the vertical intensity of the Earth's magnetic field is given in the sixth column (as derived from direct eye-readings at Potsdam and from magnetograms at Rude Skov). The reduced "zero-currents" are given in the eighth column. The two last columns show the departures from mean in ampere and in gammas, respectively. It should be mentioned that the reduction here calculated is not a complete one. The mean departure from the observations in Potsdam and Rude Skov is, respectively, 1.8γ and 1.3γ for the single determination of Z, while the mean errors of the two series are, respectively, $\pm 0.96\gamma$ and $\pm 0.71\gamma$.

As the table shows, the sensitivity of the galvanometer was not very great for the measurements given. At Potsdam a deflection of 1 mm. corresponded to about 0.00001 ampere of the compensating current or about 18γ, while at Rude Skov 1 mm. corresponded to about 0.0000054 ampere or about 10γ. Thus the observed departures may be practically explained as errors of observation almost equal to 0.1 mm. both at Potsdam and at Rude Skov. If desired, the sensitivity of the ballistic galvanometer may be considerably increased. The base-line values at Rude Skov and Potsdam having not yet been finally compiled, the results on comparison of observatory standards can not be stated at present.

Both precise standards for mutual inductance Nos. 2095527 and 2095530 were used at Potsdam and at Rude Skov, and the ratio between the corresponding "reduced" zero-currents as observed by No. 2095527 and No. 2095530 are: For all measurements of July 7, 8, 9, and 10 at Potsdam, 0.0242419/0.0227671 = 1.06478; measurements of July 19 and 23 at Rude Skov, 0.0251038/0.0235758 = 1.06481. Since this computed ratio corresponds to the ratio between the "areas" of the two standards, the close agreement at the two stations shows the electric comparison between the coils obtained through observations in the Earth's magnetic field to be superior to results that might be expected from direct measurement of their areas.

Though the new vertical-intensity magnetometer was originally built only for measuring the vertical intensity of the Earth's magnetism particularly in high latitudes, the apparatus appears useful for other purposes. Thus, a method for determining by means of this instrument the scale-value of the magnetographs will be published later in a paper dealing with the new recording device of the Godhavn Magnetic Observatory; this is a matter of large importance at stations where disturbances are nearly always present. As stated above, a precise standard for mutual inductance is peculiarly suited for transportation without change in constants. Thus, observatories equipped to measure with the necessary accuracy a current able to compensate by inductance such a standard

when turned in the Earth's field will be in position to compare readily their respective standards of intensity. The reference to one adopted standard apparatus with this method would be readily effected, and for this a standard coil for comparison purposes is retained at the Rude Skov Observatory where arrangements have been made for storing the Weston cells at a constant and rather low temperature. The Observatory will always be pleased to arrange for comparisons with this standard coil.

We will be glad to make available to instrument-makers the patterns and designs for the apparatus of the Godhavn type, including those for special resistance-boards shown in Figures 4 and 5, or to arrange for the supplying of such standard coils.

The method may be also quite evidently adapted for determination of the east-west, north-south, and horizontal components of the Earth's field. The development of our ideas in this direction must be postponed, however, until circumstances and funds permit.

The measurements with the new magnetometer thus far have been only "absolute" in that the constant K has been determined only through magnetic measurements at observatories (Rude Skov and Potsdam), where the vertical intensity was known. Meanwhile, the whole procedure of measuring invites the extension of the experiments with the view of making real absolute determinations of Z. This would require the construction of a coil, the area of which could be measured very exactly. A suggested method is to make a circular marble disc of about 70 cm. diameter, on which about 25 meters of a copper or silver band 0.01 by 1 cm. is wound in a suitable manner and under a tension, at which its length had previously been compared with a standard tape of invar such as is used in geodesy. Using every care determinations of the area could be obtained corresponding probably to a single gamma. Subsequent comparisons between the area of such a disc and that of the ordinary precise standard for mutual inductance could be made relatively easily. At present, funds are not available at the Rude Skov Observatory for the construction of such a disc.

The author wishes to express gratitude to Miss E. Schwartz for indefatigable assistance, to Dr. J. Egedal and Dr. J. Olsen for valuable help, and to Professor Dr. Adolf Schmidt, Director of the Potsdam Magnetic Observatory, for kind permission to make measurements with the new vertical-intensity magnetometer at his Observatory.

THE DANISH METEOROLOGICAL INSTITUTE,
COPENHAGEN, DENMARK, *August 9, 1926.*

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(*Continued on page 200.*)

SOME PRELIMINARY RESULTS OF DIURNAL VARIATION OF MAGNETIC INCLINATION AT FIELD STATIONS IN SOUTH AMERICA.

By H. W. Fisk.

Abstract.—The results of some of the field determinations of diurnal variation of inclination by means of observations with the earth inductor are reported; these show interesting characteristics at some of the stations along the Pacific coast of Peru and Chile. On January 27, 1917, which is one of the ten least disturbed days for the month, a total diurnal range of inclination of nearly 20′ was observed at Arequipa, Peru; observations in 1924 to 1926 show similar though somewhat smaller ranges at the same station and at other stations in the Andean region. An attempt to relate this unusual daily range to the altitude of the stations or to the nearness of high mountains has yielded only negative results. A method adopted for analyzing these partial daily curves by modification of Fourier series is described and illustrated; the resulting coefficients, though depending on certain arbitrary assumptions, are useful in comparing curves from different stations and for transferring results to other stations where they are needed for correcting field observations to a common hour for secular-variation discussions. By comparing the annual mean diurnal variation in inclination at the United States Coast and Geodetic Survey observatories with the field results here discussed, three zones for the American continents are shown within which the phase of the curves is reversed; because of the shifting of the times of maximum and minimum with the season, the central lines of these zones are only approximately determined, but they may be placed at about magnetic latitude 40° north, 0°, and 25° south.

The purpose of this paper is to make a preliminary report on some of the interesting results obtained from diurnal-variation observations in the field with ordinary field equipment. The policy of making such observations has been followed regularly for the past three years, choosing for the purpose localities at intervals of approximately 500 miles (800 kilometers). At these stations it has been possible to obtain declination and horizontal intensity results using a magnetometer for 10 or 12 hours continuously on one day, and by use of the earth inductor to obtain a like series in inclination on another day. Only the results of the inclination observations at a few of the stations are presented here; the complete report will appear later.

In January 1917, Daniel M. Wise and Allen Sterling, magnetic observers of the Department of Terrestrial Magnetism, met at Arequipa, Peru, for the comparison of their instruments. Mr. Wise had earth inductor 5 of the Schulze pattern to be used as a standard instrument at the observatory, later erected at Huancayo, Peru; Mr. Sterling had universal magnetometer 21 equipped with four dip needles. Because of what seemed to be erratic values, suggesting possible large accidental or observational errors, the work was continued over parts of six days in the interval January 24-28, 30, 1917. The type of earth inductor used by Mr. Wise is provided with a level bubble by which the axis of the coil is set

in the erect position so that when in proper adjustment, each half-set, with circle east or with circle west, may be taken as a complete determination of inclination with a comparatively small error, thus doubling the number of observations. The results of these half-sets, so taken for the several days of observation have been plotted in Figure 1. The diurnal variation is taken in the algebraic sense,

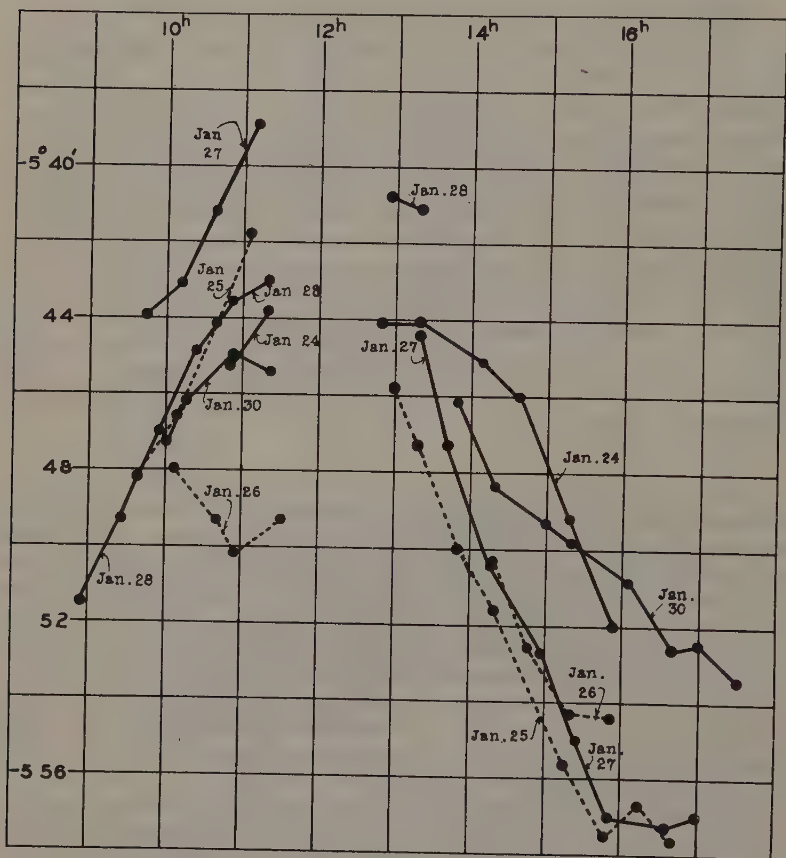

Fig. 1.—Inclination at Arequipa, Peru, January 24–30, 1917.

that is, an increasing inclination means an increasing northerly inclination or a decreasing southerly inclination. In other words, in this figure, as in those which follow, and *increasing* ordinate means a *downward* movement of the *north* end of the needle. The dots represent the observed values, each half-day's observations being joined by light lines. The morning and the afternoon observations have not been joined, inasmuch as it seems probable that the maxi-

mum inclination was reached near noon while the observers were at lunch. The trend of the morning values is always upward with the exception of those on January 26; the values on the afternoon of that day have the same downward trend shown on all the other days.

On one day, January 27, the observed values ranged from $-5° 38.'9$ at 11^h10^m to $-5° 57.'4$ at 16^h40^m with the possibility that higher or lower values were missed in making the observations. Thus the range for the day was approximately 20′ on January 27, which has been designated one of the ten least disturbed in the month by the United States Coast Survey observatories and has been given an international character number of 0.7, showing that January 27 was not a day of general disturbance. On the other days the range was similar though somewhat less. The figure also shows that the value of the inclination corresponding to any hour of the day, differed by more than 6′ on these 6 days, disregarding the anomalous values on January 26; if those are considered, a range of 11′ is observed just before noon, a fact which introduces difficulties in the attempt to correct for diurnal variation with a view to an accurate determination of annual changes.

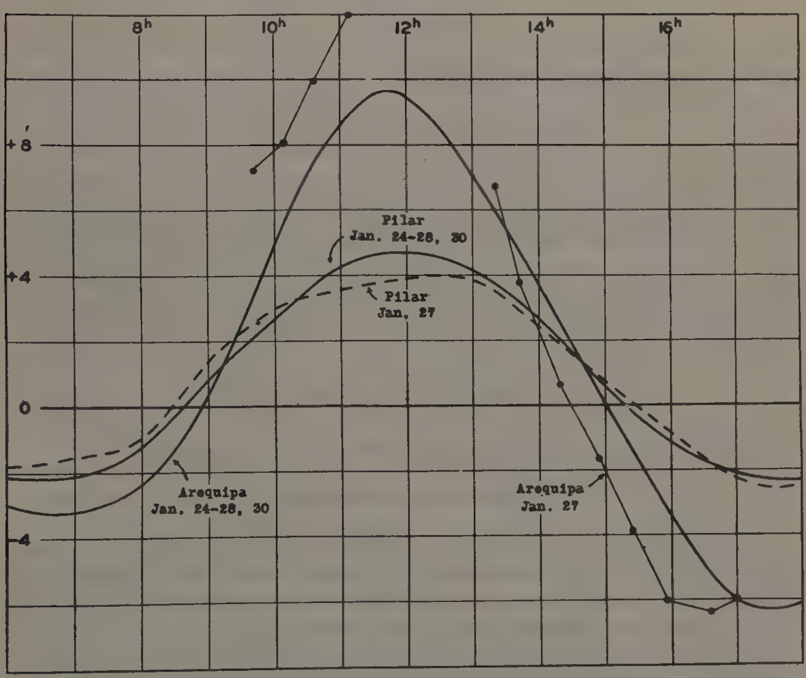

FIG. 2.—Inclination curves, January 24-28, 30, 1917, from Pilar Observatory records and from earth-inductor observations at Arequipa (see Fig. 1).

The nearest observatory to Arequipa from which hourly values for January 1917 are available is that at Pilar, Argentina, about 1200 miles southeast. Figure 2 shows a composite curve computed from all the observations during the six days at Arequipa compared with the observations on January 27. The same figure shows the mean curve of simultaneous values of the inclination computed from the published values of the horizontal and vertical components of magnetic intensity at Pilar, for the six days of the Arequipa observations and also that for the values January 27 similarly derived. Local mean time is used for both stations, that at Pilar being about one-half hour faster. The curve of daily change of the single day at the observatory does not differ greatly from the mean of all six days, and the total range of nearly 7′ at Pilar, while small compared with approximately 15′ at Arequipa, is still larger that at other stations of similar geographic latitude.

In the field, the magnetic inclination is measured directly, but at observatories it is computed from the intensity components recorded by the observatory instruments. A brief reference to the formula used in reduction may be helpful here. From the fundamental relation

$$\tan I = \frac{Z}{H} \tag{1}$$

we may write after differentiating

$$\triangle I = \frac{\sin 2I}{2}\left(\frac{\triangle Z}{Z} - \frac{\triangle H}{H}\right) \tag{2}$$

For regions where the inclination is negative each term in the second member is negative, making changes in the two components of the intensity enter into changes of the inclination in a precisely similar manner. But the second member of (2) is indeterminate when I and therefore Z is zero, and it is better after introducing the factors converting $\triangle I$ to minutes of arc, and $\triangle Z$ and $\triangle H$ to gammas, to write

$$\triangle I = 0.0344\,\frac{\cos^2 I}{H}\,(\triangle Z - \tan I\,\triangle H) \tag{3}$$

Equation (3) when evaluated for Pilar, 1917, becomes,

$$\triangle I = 0.0528\triangle H + 0.109\triangle Z \tag{4}$$

Thus while the daily ranges in values of H are very great generally in South America, amounting to well over 100 gammas and often approaching 200 gammas at Huancayo, they contribute very little to the changes in inclination so long as the inclination is small. If the daily variation curves of both vertical and horizontal components are similar in phase, it follows that they reinforce each other when combined to produce the daily variation curve of inclination. This is illustrated in Figure 3 in the upper portion of

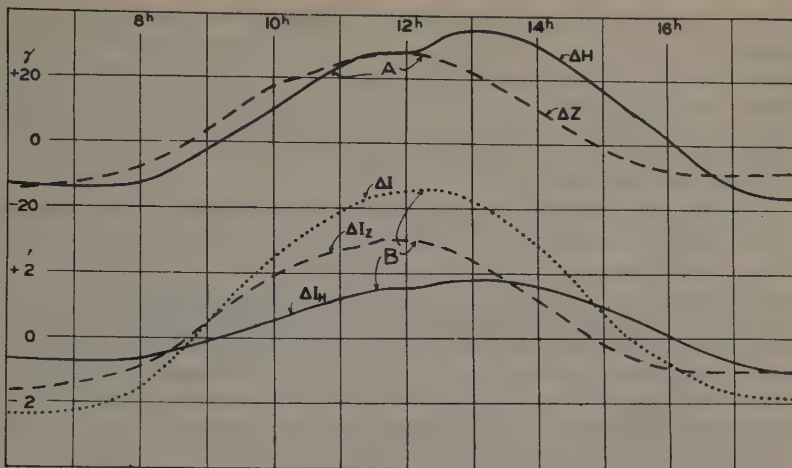

FIG. 3.—Diurnal variation in horizontal and vertical intensities (curves *A*) and contributions of intensity components to variations of inclination (curves *B*), Pilar Observatory records, January 24-30, 1917.

which has been plotted the variations of the horizontal and vertical components from the Pilar Observatory records for January 24-28, 30, 1917. In the lower part of the same figure are shown the separate and combined contributions of these components to the change in inclination. No observations were made of either of the intensity components at Arequipa in 1917, so that comparisons of changes in those elements at the two localities cannot be made until observatory results, simultaneous with more recent observations, are available.

A further opportunity for studying the interesting phenomena, just described, was presented with the inauguration of the plan of making regular observations for diurnal variations in the field, and though the value of such results is limited by their incompleteness, it is nevertheless very considerable. The observer works without trained assistance and has but one instrument (the magnetometer-inductor), therefore the inclination observations must be made on a different day from those for declination and horizontal intensity, which are observed together. The time required for making the observations necessary for one complete determination of either inclination or intensity is from 6 to 10 minutes. These observations are then repeated at intervals of 20 minutes during the day, so that the work of making them, though tiresome for the observer, is not difficult, for ample time between sets is allowed for relief from the fatigue naturally attending such close work extending over the 10 to 13 hours required. The aim is to begin the series at 6 o'clock in the morning and to continue it until 6 o'clock in the evening, but it will be readily appreciated that this condition is

always difficult and often impossible to fulfill. At some seasons the hours of daylight are insufficient, and there is no practicable provision made for artificial illumination; the observer must usually depend on local means of transportation, and he must rely on whatever means there are at hand for obtaining meals at unusual hours; instruments sometimes require unexpected attention which delays the time of beginning.

Notwithstanding the imperfections and limitations of the method a number of results have been secured which promise to yield valuable information regarding the delineation of the diurnal-variation field. In order to smooth out the unavoidable errors of observation, to eliminate irregularities due to natural causes, to provide some basis for comparison of results at different stations and fixed observatories, and to make these observations useful for correcting observations at other stations to some chosen common hour of the day, an adaptation has been made of the formulæ for harmonic analysis by use of Fourier series.

Any attempt to make use of a Fourier series as an instrument for analyzing observations covering but a portion of the 24 hours, and not repeated on succeeding days, must necessarily rest on arbitrary assumptions. The coefficients will naturally have no pretense of a physical interpretation, but they may be made of use in transferring results to other stations where they can be used for deriving approximate corrections for diurnal variation, and this was the primary purpose in mind when such work was included in the field observer's program. The first assumption made is that all the variation of practical consequence takes place during 16 hours of the 24. This assumption reduces the interval over which interpolations must be carried, reduces the number of harmonic terms required to make the computed and observed curves conform, and makes each observed quantity more important in the final result. It is then assumed that this period begins at 4^h and terminates at 20^h, the mid-point falling at 12^h noon as is customary; $15°$ consequently represents 40^m of time, or one hour is represented by $22°.5$. There will be then, in general, an interval of two hours before the first observation and a similar interval after the last observation, over which an interpolated curve must be drawn. In the curves thus far computed in this manner, the difference between the evening and the morning values is relatively small, and an interpolation curve differing from a straight line only so far as may be required to avoid unnatural abruptness has been sufficient. The form of interpolation controls to a large extent the third and fourth harmonics but has small influence on the first and second which are by far the most important. While this method of analysis is admittedly artificial, it may be questioned whether a discontinuous recurrent phenomenon, such as the cause of the diurnal variation may be, would be more naturally represented by an analysis into 24-hour and 12-hour terms with enough of the

subordinate terms to cancel the effect of the longer period terms during the inactive hours.

Space does not permit the presentation of graphs showing the results of these diurnal-variation observations, but some idea of their relative phase and range may be obtained from the table of coefficients computed on the above assumptions. Reference to an isoclinic map of the world will show that the observatories of Pilar, Samoa, and Batavia are in the same approximate magnetic latitude; the observatories of Pilar and Watheroo are not far from the same geographic latitude.

TABLE 1.—*Fourier coefficients of the 16-hour inclination curve at Arequipa, compared with those of simultaneous record at Pilar Observatory.*

Station	Date	Incl'n	c_1	α_1	c_2	α_2	c_3	α_3	c_4	α_4
		° ′	′	°	′	°	′	°	′	°
Arequipa.	Jan. 24–30, 1917	– 4 51.1	6.38	279.7	2.99	80.7	0.52	354	0.32	158
Pilar.....	Jan. 24–30, 1917	–25 42.0	3.47	265.2	1.12	89.2	0.06	288	0.16	291

In Table 1 the Fourier coefficients for the mean observed inclination curve for Arequipa, January 24-28, 30, 1917 and the simultaneous curve from Pilar, shown in Figure 2, are given. The third and fourth harmonics are of little significance as they are largely influenced by the interpolated values in the case of the field observations, and by the non-cyclic corrections in case of the observatory results taken, as here, for but 16 hours of the days used. It will be noted that the phase angles for the first two harmonics are quite similar but that the amplitudes at Arequipa are approximately twice those at Pilar.

TABLE 2.—*Fourier coefficients of the mean 16-hour inclination curve at Pilar Observatory, compared with those from observatories in comparable magnetic and geographic latitudes.*

Station	Date	Incl'n	c_1	α_1	c_2	α_2	c_3	α_3	c_4	α_4
		° ′	′	°	′	°	′	°	′	°
Samoa.....	Dec. 1911	—29 37.0	0.95	271.2	0.30	138.9	0.06	6	0.00	....
Pilar.......	Jan. 1920	—25 41.5	2.24	276.7	0.56	88.6	0.08	293	0.10	292
Batavia....	Jan. 1920	—31 50.8	1.64	254.8	0.37	65.6	0.07	16	0.02	0
Watheroo...	Jan. 1920	—63 51.1	0.52	292.6	0.30	72.8	0.03	18	0.02	63
Batavia....	Mar. 1920	—31 54.0	1.83	268.4	0.63	170.5	0.13	90	0.03	241
Watheroo...	Mar. 1920	—63 54.6	0.06	279.5	0.30	28.3	0.01	225	0.07	328

In Table 2 a further comparison of the same coefficients has been made between Pilar Observatory and Batavia and Samoa observatories in approximately the same magnetic latitude, and be-

tween Pilar and Watheroo in similar geographic latitude. Pilar, Watheroo, and Batavia, are mean values for January, 1920, but because the records for that month were not at hand those for December 1911 were substituted in the case of Samoa. The last two lines are added to show that the amplitudes increase from January to March for Batavia, while they diminish over the same interval at Watheroo; the time of occurrence of maximum is also shifted in opposite directions at the two stations.

With the unusual diurnal variation at Arequipa in mind, Mr. John Lindsay, an observer of the Department of Terrestrial Magnetism, in the course of a field expedition for obtaining secular-variation data made observations there in December 1924 and at other stations in the same general region. Unfortunately the day of the diurnal-variation observations at Arequipa was disturbed so that the daily curve was somewhat abnormal, but an opportunity to repeat the work was afforded on his return from field work in Brazil and Argentina in February 1926. The table which follows combines the results of four series at Arequipa, two series at Juliaca and one series at Mollendo. The last named place is a seaport, Juliaca is near Lake Titicaca at an elevation of more than 12,500 feet, while Arequipa lies between the two places at an elevation of approximately 7,500 feet. The first and second columns give the geographic coordinates, the latitude, ϕ, to the nearest tenth-degree, the longitude, λ, in hours west of Greenwich; the third column, ϕ' is the magnetic latitude from the relation $\tan\phi' = \frac{1}{2}\tan I$; the last two columns give the local mean time of the principal maximum and the daily range, R, in inclination, taken from the computed curve.

TABLE 3.—*Comparing phase and amplitude of inclination curves at stations of greatly different elevations.*

Station	ϕ	λ	ϕ'	c_1	α_1	c_2	α_2	L. M. T.	R
	°	h		′	°	′	°	h	′
Arequipa..........	16.4S	4.8	−2.9	3.66	296	2.20	225	11.4	11.1
Mollendo..........	17.0S	4.8	−3.3	1.77	278	1.39	139	10.9	5.3
Juliaca............	15.5S	4.7	−1.4	1.86	243	0.86	97	11.8	5.1

Although Arequipa lies between the other stations which are less than 200 miles apart, and is intermediate also in elevation above the sea, the range of daily variation in inclination observed there was twice that observed at either of the other two places. Sufficient observations have been made at Arequipa to make it safe to assume that the observed range is characteristic in general. The two days at Juliaca were separated by more than a year; the two curves were substantially identical, and were confirmed by an incomplete day's work at La Paz, Bolivia, at the southeast end of the lake about 130 miles southeast of Juliaca and at about

the same elevation. Only one day's work was done at Mollendo, and there is some reason to suspect that greater ranges than that on the day of the observations might generally prevail. At Antofagasta, a seaport in Chile about 500 miles farther south, a range of more than 11′ was observed on one day, indicating conditions comparable with those at Arequipa.

The range then is not a simple function of geographic latitude, nor of magnetic latitude; it does not appear to be directly associated with elevation above the sea, but is rather caused by some condition affecting limited regions. That there is a large amount of local disturbance arising from the uneven distribution of volcanic rocks of magnetic character, is shown by the observations and by samples of the rocks and sand. The presence of the volcano, El Misti, 20,000 feet in altitude near Arequipa, and of Aconcagua, 23,000 feet in altitude between Valparaiso and Mendoza where other large variations have been found, suggest interesting subjects for speculation. The amount of information is at present altogether insufficient for a profitable discussion of that suggestion.

TABLE 4.—*Comparing phase and amplitude of inclination curves at stations in South America having south magnetic latitude.*

Station	Date	ϕ	λ	ϕ_1	c_1	a_1	c_2	a_2	L.M.T.	R
		°	h	°	′	°	′	°	h	′
Cuyaba........	Aug. 26, 27, 1925	−15.6	3.7	− 0.3	1.07	226	0.28	111	13.4	3.2
Goyaz.........	Oct. 18, 1925	−15.9	3.3	− 1.4	2.75	239	1.38	100	11.7	8.4
La Paz.........	Dec. 16, 1924	−16.5	4.5	− 1.9	2.33	242	1.41	98	12.0	6.5
La Quiaca......	Jan. 30, 1926	−22.1	4.4	− 6.5	3.48	326	3.32	162	11.0	12.7
Concepcion.....	Jul. 22, 1925	−23.4	3.8	− 6.8	1.69	279	0.80	90	11.4	4.2
Antofagasta....	Jan. 2, 1925	−23.6	4.7	− 8.6	4.65	293	2.34	106	11.3	11.2
Porto Alegre....	Dec. 8, 1925	−30.0	3.4	−12.3	2.11	284	0.76	149	12.0	4.9
Colon..........	Dec. 26, 1925	−34.8	3.7	−15.1	3.71	294	1.25	160	10.6	7.0
Mendoza.......	Jan. 9, 1926	−32.9	4.6	−15.4	2.74	242	0.87	94	12.7	8.9
Valparaiso......	Feb. 2, 1925	−33.1	4.8	−16.2	3.88	271	1.23	114	11.3	7.8
Bahia Blanca...	Jun. 15, 1925	−38.8	4.2	−18.3	0.57	286	0.52	167	11.6	3.0
Puerto Montt...	Feb. 16, 1925	−41.5	4.8	−22.8	2.65	295	0.68	101	11.0	6.5
Puerto Deseado.	May 23, 1925	−47.7	4.4	−25.5	0.12	281	0.34	325	14.2	0.9
Port Stanley....	Apr. 7, 8, 9, 1925	−51.7	3.9	−27.2	0.41	86	0.72	296	16.6	1.6
Punta Arenas...	Mar. 5, 1925	−53.2	4.7	−30.3	1.67	110	0.98	279	16.7	4.4

The results of variation observations at other places in South America having negative vertical intensity are shown in Table 4, giving the same details as Table 3. Seasonal variations are unavoidably combined with variations due to geographic position, but it is believed that in a general way the results are representative. The arrangement of stations is according to increasing negative magnetic latitude, and it will be noted that the local mean time of the (algebraic) maximum inclination is near midday as far south as Puerto Montt, Chile. At Puerto Deseado, Argentina, the observa-

tions were made in the southern winter, and the resulting range was less than one minute, the maximum of the rather indefinite curve falling later than for stations farther north. At Port Stanley, Falkland Islands, the observations were made on three separate days, but owing to what seems to have been some instrumental trouble difficult to locate and correct, there was an unusually large error of observation. The mean result however distinctly showed a minimum instead of a maximum near midday, while the maximum occurred quite late in the afternoon. At Punta Arenas, on the Straits of Magellan, this change of phase of the curve was very definite and was accompanied by a greatly increased range.

An interesting cross section of the diurnal-variation field may be obtained by comparing the curves of diurnal variation of in-

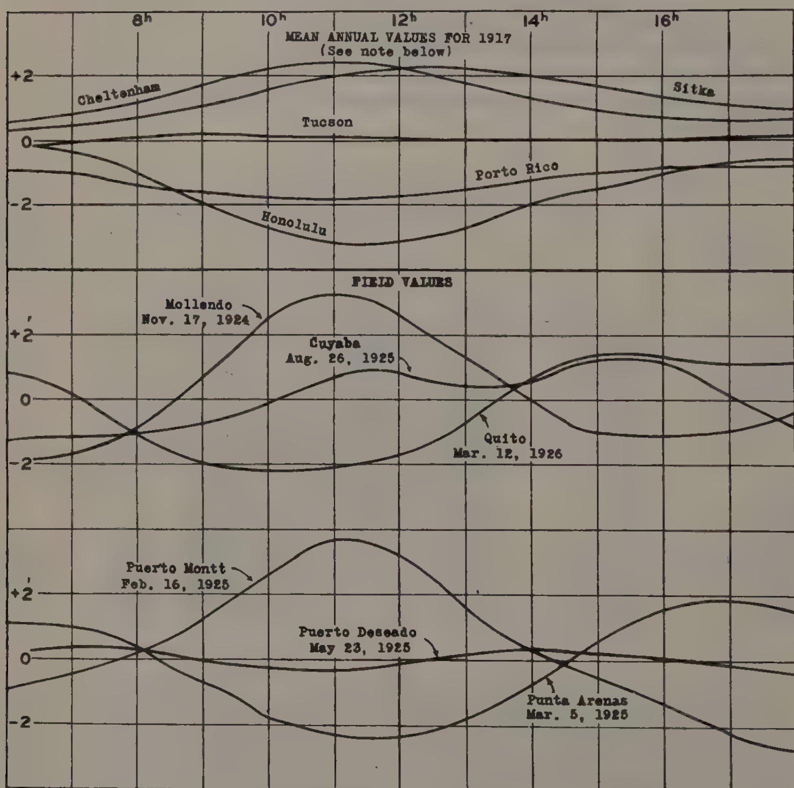

FIG. 4.—Inclination diurnal-variation curves. (*Note.*—All ordinates for Sitka and Cheltenham have been increased, and for Porto Rico and Honolulu, decreased by 1′, to avoid confusion in drawing. The mean values for the field curves are the 16-hour means as computed by the method described.)

clination at selected stations in the western hemisphere from Alaska to Patagonia as in Figure 4. The upper portion of the figure presents the mean annual variation in inclination at each of the five United States Coast and Geodetic Survey observatories for the year 1917, arranged according to magnetic latitude. It will be seen that a reversal of phase occurs somewhere in the region of southern United States or northern Mexico. Along this belt there is a large seasonal change of phase although the change in amplitude from month to month is not so large as at the northern observatories. At Tucson the interference due to this change of phase is so great that the daily curve becomes nearly a straight line. At Vieques the seasonal phase-change is also large but leaves a well-defined curve in the annual mean.

The central portion of Figure 4 represents curves from field observations on single days only at the three stations. In a more general way a similar reversal is seen within the belt along the magnetic equator. The Huancayo Observatory lies in this belt, and the record now being prepared for publication will show change of the phase with the meridian zenith-distance of the Sun. Instead of the Huancayo results, not yet ready for publication the mean of two series at Cuyaba, Brazil, made August 26 and 27, 1925, has been used. The lower portion of the figure represents the reversal in Patagonia already described. The positions and magnetic latitudes of these stations are given in the following table.

TABLE 5.

Station	Date	Lat.	Long. W. of Greenwich	Incl'n	Magnetic Lat.
		° ′	° ′	° ′	°
Sitka	Annual mean 1917	57 03 N	135 20	+74 25	+60.8
Cheltenham	" " 1917	38 44 N	76 50	+70 52	+55.3
Tucson	" " 1917	32 15 N	110 50	+59 26	+39 3
Vieques	" " 1917	18 09 N	65 27	+51 03	+31.7
Honolulu	" " 1917	21 19 N	158 04	+39 27	+22.4
Quito	March 12, 1926	00 13 S	78 33	+21 05	+10.9
Cuyaba	August 26-27, 1925	15 37 S	56 06	−00 39	−00.3
Mollendo	November 17, 1925	17 02 S	72 01	−06 36	−03.3
Puerto Montt	February 16, 1925	41 29 S	72 59	−39 58	−22.8
Puerto Deseado	May 23, 1925	47 49 S	65 55	−43 34	−25.5
Punta Arenas	March 5, 1925	53 10 S	70 52	−49 27	−30.3

So far as one may venture to form conclusions from such fragmentary data, it may be inferred that the belts of inversion of these variation curves are not symmetrically disposed with reference to either the geographic or the magnetic equator. The southern belt is approximately 15° farther removed from the geographic

equator, while it is the same number of degrees nearer the magnetic equator than the northern belt; the table also suggests that the two belts are nearly 90° of latitude apart, allowance being made for seasonal change of position.

As was pointed out by the writer in a paper[1] discussing the secular variation in South America, that continent presents an unusual opportunity for observing the behavior of magnetic variations. Unfortunately the number and distribution of observatories is quite insufficient to furnish the material which any adequate discussion of these interesting problems requires. Until such can be provided it is hoped that organizations able to extend their usual field programs so as to include observations of diurnal variations may do so, for it is evident that such data, fragmentary though they may be, are still of great value, not only for the original purpose of supplying corrections to mean of day to be applied to field observations, but for providing a real contribution to our knowledge of the underlying causes of those variations.

[1]Preliminary lines of equal annual change of the magnetic elements in 1915 for Latin America and adjacent waters, *Terr. Mag.*, Dec. 1924.

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COMPARISON MEASUREMENTS BETWEEN THE ABINGER AND THE N. P. L. STANDARD HORIZONTAL FORCE MAGNETOMETERS.

By D. W. Dye, B.Sc.

(Of the National Physical Laboratory).

I. Introductory.

The National Physical Laboratory possesses a standard Absolute Horizontal Force Magnetometer based on a method due to Schuster[1]. The construction and use of this magnetometer has been fully described in a paper[2] by F. E. Smith.

A second similar instrument has recently been completed and set up at the new Royal Magnetic Observatory at Abinger, Leith Hill. This instrument is of precisely the same design and arrangement as its prototype but the dimensions of the windings are $\frac{5}{6}$ths those of the original instrument. Small detail improvements are also incorporated in the new instrument. Before setting up the magnetometer at Abinger it was considered to be a unique opportunity to compare the performance of two such instruments when set up sufficiently near to one another that the magnetic field measured by each might be considered the same.

They were accordingly set up on two stone piers about 2 metres apart in the magnetic hut at the Laboratory and a careful series of observations forming the comparison was made. These and the results together with a short account of the behavior of the second instrument as permanently set up at Abinger form the subject of this note.

II. Principle of the Magnetometer.

Although the principle of the magnetometer has been fully described in the paper[2] referred to, it will render this note more clear if a very brief outline of the principle is included here.

The magnetometer consists essentially of a Helmholtz-Gaugain coil system in the form of two short windings of bare wire wound as spirals upon a marble cylinder in such a manner that the mean diameters and distance apart of the turns may be measured to the highest accuracy possible. This system is supported with its axis horizontal upon a cradle which permits it to be revolved about a truly vertical axis.

[1] *Terr. Mag.*, May, 1914.

[2] *Phil. Trans.*, Vol. ccxxiii, p. 178.

Auxiliary apparatus enables a smoothly variable current to be adjusted to an accurately known value. The current when passed through the windings of the magnetometer provides an accurately known horizontal magnetic field. This field can be oriented about the vertical axis so that it may subtend a known angle to the Earth's horizontal field.

The most convenient method of observation, when using the instrument, is to provide, by adjustment of the current, a field which is accurately known and which is slightly greater than H. The coil system is then turned about the vertical axis until the component of its field at the centre along the direction of H is exactly equal in value and opposed in direction to H. Under these conditions the resultant field is small and is exactly at right angles to H. The value is then given by the very simple relation

$$H=H_c \cos \alpha$$

where H_c is the field given by the coil and α is the angle which this field makes with H. If α is kept small—of the order of 2° or 3°—its cosine is very nearly unity and a small uncertainty in the angle is of very little effect indeed upon the accuracy of the determination of H.

A small indicator magnet suspended with negligible torsional control serves to show when the adjustment of α has caused the resultant field to be at right angles to the Earth's horizontal field.

There are two angular positions of the coil system at which the component of H_c along H is exactly equal to H. In an entirely perfect instrument the two angles α, β are exactly equal. But owing to small errors of alignment, to variations in the direction of the Earth's field and to a small amount of torsion in the suspension, the second angular position at which the resultant field is exactly reversed in direction, occurs at an angle which is not exactly equal to α but which, when the adjustments are satisfactory differs from it by only a few minutes of angle.

In the normal use of the instrument the two angles α and β are observed and the Earth's horizontal component is then given by the simple expression

$$H=H_c \frac{\cos \alpha+\cos \beta}{2}$$

Any small residual torsion in the suspension or departure from a right angle between the resultant field and the Earth's horizontal field at the settings α and β of the coil system becomes of negligible influence upon the mean measurement of H. This is true provided that the two resultant fields corresponding to the positions α and β are strictly at 180° to one another. By the use of aligning mirrors, this condition can be realised with very great accuracy.

III. Constructional and Dimensional Comparisons Between the Two Instruments.

The two magnetometers have both been constructed at the N. P. L. The accurate measurements of the diameters and pitches of the windings have also been carried out to the highest possible accuracy in the Metrology Department in terms of the line standards of the Laboratory.

In what follows, the original instrument will be always referred to as the N. P. L. magnetometer and the copy, now at Abinger, will be referred to as the Abinger or *A* magnetometer.

The constructional details of the N. P. L. magnetometer are admirably set out in F. E. Smith's account of the instrument and the measurements made by it (2).

The Abinger instrument, as mentioned, has dimensions closely approximating $\frac{5}{6}$ths those of the N. P. L. instrument. Its construction is otherwise identical except for minor improvements. The Abinger magnetometer differs from the N. P. L. instrument in the following particulars:

(a). The windings are of hard drawn silver wire.

(b). The mirrors on the magnet box are provided with fine adjustment screws.

(c). The small magnet is of cobalt steel.

(d). The marble cylinder is provided with small platinum reference plugs in order that its diameter and length may be remeasured at any future time without dismantling the instrument.

(e). Switches are provided with plug arrangements so that any or all of the coils may be shortcircuited when desired.

The use of a cobalt steel indicator magnet greatly shortens the time of swing of the system. When the adjustment of current is such that the angle α is only 2° or less, the resultant field is of course very small so that the time of swing of the magnet necessarily becomes rather long. The increase in the ratio of the magnetic moment of the cobalt steel magnet to its moment of inertia as compared with that of a tungsten steel magnet is of great value in this respect.

The addition of reference plugs on the marble cylinder and the provision of standard invar gauges is also considered of importance in ascertaining any secular changes in the dimensions of the marble. The gauges can be applied to the reference plugs and by the aid of reading microscopes comparative measurements can be made at any time without in any way disturbing the instrument.

Constants of the windings.—The constants of the two magnetometers are set out in the table below. The measurements all refer to a temperature of 17 C.

	N.P.L. (1921)	*Abinger (1926)*
Mean dia. of windings in cm......	60.001_9	50.009_5
Length between mean planes in cm.	30.009_8	25.011_6
Turns in each winding...........	12	10
Constant F such that $H_c = F \times i/10$	3.59595	3.5954_4
Temp. coeff. of F per 1° C rise ...	-7.9×10^{-6}	-4.3×10^{-6}

The calculations of F are based on the mean diameters and mean distance apart of the two halves of the windings. The effects of conicality and irregularity of pitch are entirely negligible.

In connection with these measurements it must be mentioned that the diameter and pitch measurements on the N. P. L. instruments were made in 1921. There is a possibility that small secular changes have occurred during the interval of 5 years that has elapsed. The measurements will probably be repeated at a future date, but any changes are at present unknown and have been ignored.

IV. Comparison Measurements of H by the Two Magnetometers.

It was considered of interest to compare the two magnetometers under nearly identical conditions in order to see what agreement would be obtained between the theoretically and the experimentally determined ratio of their constants.

The two instruments were therefore set up on stone piers about 2 metres apart in the magnetic hut specially built for the N. P. L. instrument. The line joining the centres of the instruments was approximately magnetic east and west. The comparisons consisted in alternate measurements of H by the two instruments.

(a.) Adjustments.

The instruments were carefully levelled so that the axes of the marble cylinders were truly horizontal. The mirrors on each needle box were aligned so as to enable the rectangularity of resultant field with the Earth's field to be established with accuracy when the coil was oriented through the angles α and β, respectively. The lamps were adjusted and the scales were drawn and set so that the angles α and β could be observed to an accuracy of reading of 1 minute of angle. The torsion was removed from the suspension of the indicating magnet in each instrument. Since the constants of the two instruments are so nearly identical, the same current was used in the windings on each. For this purpose they were connected in series.

The current-measuring arrangements consisted of a standard resistance of about 2 ohms in series in the main current circuit. The potential difference at the terminals of this resistance was balanced by a Weston Standard Cadmium Cell of which the voltage was known to one or two parts in a hundred thousand.

The standard resistance could be shunted by other resistances of 200, 250 or 300 ohms so as to bring the current to values suitable to cause the angles α and β to be of order 3° to 5°.

The current was continuously regulated by hand by means of smoothly adjustable resistance in series in the current circuit.

An observer maintained the balance on the galvanometer in the standard cell circuit to a precision such that the variations seldom exceeded one part in a hundred thousand.

(b). Preliminary Precautionary Experiments.

In order to ascertain that mutual effects between the two magnetometers were of negligible consequence, the following tests were made:

Effect of the needle of one instrument on the other.—Current was passed through the windings of both instruments but the sections of the windings of one instrument were connected in opposition to one another so as to render the coil system nominally inactive. The axis of the coil of the other magnetometer was turned and adjusted to the angle α as in use so that the resultant field was at 90° to the Earth's horizontal field. In this position it is very sensitive to a parasitic field in the direction of the Earth's field. With the magnetometer in this condition, the magnet on the other magnetometer was oriented into various positions along the meridian and at right angles thereto. No observable deviation of the magnet of the first magnetometer was found at any angular setting of the magnet of the second instrument. Since, however, the effect, if any, would be a minimum when the stray field from one magnet had a direction along that of the other magnet, i.e., perpendicular to the Earth's field, the magnet of the magnetometer not in use was always set to produce this minimum effect.

The *other possible cause of error* associated with the proximity of the two magnetometers is the stray magnetic field of the coil system of one magnetometer upon the magnet of the other. The method of comparison requires the current to be always flowing through the windings of both instruments. Each half of the coil system of each magnetometer consists of a bifilar two-start helix. These can be connected in opposition by means of a reversing switch thus rendering the magnetic field zero at all regions not extremely near the wire of the windings. In order to see whether the neutralisation was perfect, the coil of the magnetometer with windings reversed was oriented round and any effect on the magnet of the other instrument was carefully looked for. No observable effect could be detected.

A minute effect of the reversed magnetometer windings upon its own magnet was however observed, due to residual fields from the narrow loops formed by the cross-connecting leads between one half and the other of the Helmholtz system. The arrangement of these leads is such that this residual field only appears when the windings are in opposition. The residual field at the magnet due to these loops is zero when the instrument is used with the windings connected additively in the normal way.

(c). Procedure of the Observations.

The current through the two windings was maintained at a suitable value to a constancy of about one part in a hundred thousand throughout a series of observations of α and β. Two main series of observations were taken. The current was slightly altered

—by the use of a different shunting resistance on the standard resistance in the second series of observations so as to give a somewhat different case with different mean values of α and β.

The observations were made as follows:

(i) The windings of A were connected in opposition and the coil was set approximately with its axis along the meridian.

(ii). The observations of the angles α and β were made in the order given on the *N. P. L.* magnetometer. The times at which these observations were made were noted.

(iii). The windings of the *N. P. L.* were connected in opposition and its coil and needle left as at balance in the β position. The windings of A were connected in the additive direction.

(iv). Observations of α and β were made on the A instrument. The times were noted.

(v). The coil and needle of A were left in the β position and the windings connected in opposition.

On returning to the N. P. L. instrument, after connecting the windings additively, the readings were taken in the order β then α and the magnet was then left in the position corresponding to the α reading during the next observation on A i.e. 180° displaced from its position at the previous observation on A.

In averaging the results therefore, any slight unnoticed residual cross effects of one neede on the other will be alternately positive and negative.

The temperatures of the windings were noted at intervals of about 15 minutes.

During the observations, a continuous magnetograph record was taken on a photographically-recording apparatus arranged for variations in horizontal intensity. Time markings and calibrations were made during the run in order to permit proper correlation of the record with the absolute intensity observations on the magnetometers.

A preliminary series of observations was taken on Mar. 7th between the hours of 12 and 13 G.M.T., in order to check the satisfactory behaviour of all the apparatus. Owing to large and sudden fluctuations in H resulting from the running of trains and trams in the neighbourhood, these observations were in themselves of little value. The more accurate series of observations as made in the early morning of March 9th between the hours of 0^h30^m and 2^h30^m G.M.T.

The first of these series of observations were made using a current such that the angles α and β were approximately 4°—30′; in the second series the current was reduced to such a value that the angles α and β were about 3°—0′. Magnetograph records taken on preceding days showed that the horizontal intensity was not particularly steady so that it was decided not to reduce α below 3° on account of the risk of instability which would occur should H temporarily rise to a value greater than H_c.

The results of the first series of observations are given in Tables I and II.

TABLE I.—*N. P. L. Magnetometer, Series I, March 9, 1926.*

Time G. M. T.	$\frac{\cos\alpha+\cos\beta}{2}$	Diffs. from mean of column 2; parts in 10^6	Differences in γ units	Temp. C.
h m				°
0 30	0.99655	+ 70	+1.4	19.4
0 39	0.99650	+ 20	+0.4	
0 49	0.99636	−120	−2.2	
0 56	0.99664	+160	+2.9	19.5
1 07	0.99642	− 60	−1.1	
1 17	0.99666	+180	+3.3	
1 25	0.99635	−130	−2.4	19.3
1 32	0.99650	+ 20	+0.4	
1 38	0.99642	− 60	−1.1	
1 45	0.99640	− 80	−1.5	19.3

Mean value of $\frac{\cos\alpha+\cos\beta}{2}=0.99648^0$; corrected value for scale error $=0.99644^5$.

TABLE II.—*Abinger Magnetometer, Series 1, March 9, 1926.*

Time G. M. T.	$\frac{\cos\alpha+\cos\beta}{2}$	Diffs. from mean of column 2; parts in 10^6.	Differences in γ units	Temp. C.
h m				°
0 28	0.99673	+120	+2.2	19.3
0 35	0.99670	+ 90	+1.6	
0 45	0.99646	−150	−2.7	
0 53	0.99673	+120	+2.2	19.2
1 01	0.99645	−160	−2.9	
1 13	0.99663	+ 20	+0.4	
1 20	0.99672	+110	+2.0	19.2
1 28	0.99654	− 70	−1.3	
1 35	0.99666	+ 50	+0.9	
1 42	0.99651	−100	−1.8	19.2

Mean value of $\frac{\cos\alpha+\cos\beta}{2}=0.99661^3$; corrected value for scale error $=0.99654^5$.

The second series was somewhat shorter than the first but was otherwise very similar. The mean corrected values of $\frac{\cos\alpha+\cos\beta}{2}$ for the two instruments were:

N. P. L., 0.99845^4; Abinger, 0.99855^3.

In Table III are given the collected results including the values of current and coil constant at the temperatures concerned. In the last column are given the deduced values of H in C.G.S. measure.

TABLE III.

N. P. L. Magnetometer (F at 19°.3 = 3.59588).

Series	Mean corrected $\frac{\cos\alpha+\cos\beta}{2}$	I (C. G. S.)	H (mean) C. G. S.
I	0.99644^5	0.051431^0	0.18428^2
II	0.99845^4	0.051329^4	0.18428^9
	Abinger Magnetometer (F at 19°.2 = 3.59541).		
I	0.99654^5	0.051431^0	0.18427^6
II	0.99855^3	0.051329^4	0.18428^3

It will be seen that the difference between the values of mean H as determined by the two magnetometers is only 0.6 γ, and that this difference is the same for each series of measurements. The agreement between the two magnetometers may be considered extremely satisfactory. It is probably within the limits of uncertainty associated with all the links in the chain connecting the two values of H.

The difference between H for Series I and Series II is probably real. This is corroborated by the magnetograph chart.

In view of the fairly quick variations in H shown by the record it is clear that ten observations on each instrument are barely sufficient to justify the assumption that the same real mean value of H is a basis for comparison.

V. Observations made at Abinger.

The Abinger magnetometer has been permanently installed in the magnetic observatory there and daily base-line values of H are regularly determined by it.

A typical and fairly complete series of determinations so made on August 1 are given in the accompanying Table IV.

I am indebted to Mr. Witchell of Greenwich Observatory and to the staff of the Abinger Magnetic Station for these observations of H and for the deduced base-line values computed in conjunction with the magnetograph records taken on enlarged scales of H and time for the purpose of this note.

The table is given exactly as received from Abinger.

Comments.—In the last column of Table IV are given the differences from the mean base-line. These differences include inaccuracies in the absolute measurements and uncertainties associated with the recording magnetometer. The sensitivity of the latter is of the order 1.2 mm. for a change of 1γ. It will be seen that the differences between the magnetograph record and the base-line vary from zero to 40γ. The uncertainties associated with the calibration etc. of the magnetograph will therefore not be negligible.

The mean difference without regard to sign for all the thirty observations is only 0.6γ, and the maximum differences are about twice this amount. It seems reasonable to conclude that the values

TABLE IV.—*Royal Observatory, Greenwich, August 1, 1926.*

(Determination of the value of the base-line of the H. F. Magnetometer at the Abinger Magnetic Station, Surrey, from observations with the Schuster-Smith Coil Magnetometer. The scale value of the magnetograph, adopted from two determinations is 1mm. = 0.835γ. The enlarged time scale of 180mm. to the hour was used.)

G. M. T.	Observed horizontal force γ	Corres. ordinate on magnetogram		Deduced base-line value	Apparent error of absolute observation
h m	γ	mm	γ	γ	γ
4 45 –47⅓	18595.6	+ 0.3	+ 0.3	18595.3	+1.6
53 –54½	82.0	−15.5	−12.9	94.9	+1.2
55½–56½	81.8	16.0	13.4	95.2	+1.5
57½–59	82.0	15.3	12.8	94.8	+1.1
5 2½– 5	71.4	27.0	22.5	93.9	+0.2
5½– 6½	65.3	34.0	28.4	93.7	0.0
7 – 8	65.5	34.1	28.5	94.0	+0.3
12 –13½	62.7	36.8	30.7	93.4	−0.3
15½–17⅓	62.2	37.0	30.9	93.1	−0.6
35 –36	63.2	35.5	29.6	92.8	−0.9
38 –39	62.5	37.0	30.9	93.4	−0.3
40 –42	62.0	37.5	31.3	93.3	−0.4
51 –52	62.4	37.8	31.6	94.0	+0.3
54½–55⅓	63.0	37.2	31.1	94.1	+0.4
57½–58¼	63.2	37.3	31.1	94.3	+0.6
59½– 0½	61.9	38.4	32.1	94.0	+0.3
6 3½– 4½	61.1	39.0	32.6	93.7	0.0
5¼– 6	61.5	39.0	32.6	94.1	+0.4
7 – 8	61.5	39.4	32.9	94.4	+0.7
9 –10	61.1	39.0	32.6	93.7	0.0
11 –12	60.0	40.0	33.4	93.4	−0.3
13½–14½	59.3	41.0	34.2	93.5	−0.2
15⅓–16	57.3	42.1	35.2	92.5	−1.2
17 –18⅓	57.4	43.0	35.9	93.3	−0.4
19⅓–20	57.8	43.5	36.3	94.1	+0.4
20½–21½	56.8	42.9	35.8	92.6	−1.1
23 –24	57.2	42.5	35.5	92.7	−1.0
24½–25½	58.3	42.0	35.7	93.4	−0.3
26½–27	58.0	41.0	34.2	92.2	−1.5
28 –29	58.4	41.1	34.3	92.7	−1.0
			Mean	18593.7	

of H as determined by the magnetometer have an inaccuracy and uncertainty of value not greater than 1γ and that this measure of reproducibility in base-line value can be attained by careful observation and calibration of the complete equipment. It is understood of course that the natural variations in H are reasonably small and slow in amount and rate during the determinations.

In conclusion, my thanks are due to Mr. S. Watts who assisted ably in adjustment of the current and preparation of the magnetograph records at the Laboratory, to Mr. Witchell and staff in connection with the results obtained at Abinger and to Sir Arthur Schuster and the Director of the Laboratory for kindly interest in the measurements.

September 23, 1926.

EARTHQUAKES REGISTERED ON THE LUKIAPANG MAGNETOGRAPHS IN 1925.

The list of earthquakes contained in our last pamphlet (Études, XXIV) could not be kept in order without an amount of labor. Something like what is done at the Watheroo Magnetic Observatory would perhaps be acceptable. It is not yet time to give the epicenters, but we can supply the number of the Zikawei Bulletin and a calculated distance, also the phase which seems nearest.

The *type* can be given according to what is said (Études XXIV, p. ii, §iv).

The hour given is that of the bifilar mark, the others not being discussed.

Date 1925	G. M. T.	Type	Magneto-graphs	Zikawei No.	G. M. T.	Phase	Epi-center
	h m				h m	h m	*km*
March 16	14 51	c c c	H, D, Z	4153	14 47	S 14 50	Talifu
April 2	22 50	a c	H, D	4163	22 48	eS 22 50	
" 7	18 25	b	H	4165	18 48	M 18 23	2400
" 16	19 58	a a c	H, D, Z	4169	19 55	Mz 19 58	1010
May 3[1]	17 27	a	H	4179	17 28	iPz 17 28	3130
" 24	1 27	a a	H, D	4201	1 26	P 1 26	790
" 27	2 35	a a	H, D	4206	2 33	iS 2 35	1360

[1]The earthquake seems to have been recorded here first, though the distance of the epicenter is not very small, but perhaps we cannot reckon one minute only. The same shock was felt at Watheroo at 17^h36^m. One may note that the shock of June 9th at Watheroo is No. 4216 of Zikawei, not registered here, but recorded at Zikawei at 13^h48^m, seven minutes before Watheroo.

J. DE MOIDREY, S. J.

ZIKAWEI OBSERVATORY,
SHANGHAI, CHINA.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE CHELTENHAM MAGNETIC OBSERVATORY, JULY TO SEPTEMBER, 1926.[1]

(Lat. 38°44′.0 N.: long. 76°50′.5 or $5^h07^m.4$ W. of Gr.)

Greenwich Mean Time		Range		
Beginning	Ending	Decl'n	Hor. Int.	Vert. Int.
1926 h m	d h m	′	γ	γ
Sep. 8 10 ..	9 10 ..	46.9	96	100
15 13 ..	16 6 ..	31.9	131	189
20 15 ..	21 24 ..	64.8	251	282+*

*Trace off sheet.

[1]Communicated by E. LESTER JONES, Director, United States Coast and Geodetic Survey.

GEO. HARTNELL, *Observer-in-Charge.*

INVERSION DE L'INCLINAISON MAGNÉTIQUE TERRESTRE AUX ÂGES GEOLOGIQUES.

Les laves volcaniques en se refroidissant dans le champ magnétique terrestre y prennent une aimantation rémanente, en général faible, mais très stable et bien représentative de ce champ en direction et sens. Un échantillon de la roche, prélevé après repèrage géographique *in situ* et analysé magnétiquement, nous renseignera donc sur la distribution du champ magnétisant à l'endroit et à l'époque de sa consolidation. C'est, en effet, après que le magma s'est figé et que le refroidissement en a ábaissé la température à un certain degré, vraisemblablement voisin, (sinon identique) du "point de Curie" de la magnétite (580°) que la dite aimantation s'établit. Remarque essentielle: à cette température la roche est déjà fort éloignée de l'état de fusion pâteuse et ne peut plus fluer notablement; ceci exclut donc la possibilité d'un changement de situation de la lave par écoulement après aimantation prise. Bien entendu, il faut réserver les changements de position d'ordre tectonique qui ont pu affecter ultérieurement la coulée de lave, mais le cas du retournement complet de la coulée paraît de prime abord exclu de la réalité. On a donc le droit, si une lave décèle une aimantation de sens opposé à celle que le champ terrestre actuel lui imposerait, d'en conclure à une inversion originelle de ce champ. Les belles recherches de M. Chevallier[1] sur les laves de l'Etna ont démontré que pour la déclinaison ces renseignements tirés des laves sont très sûrs et précis. Pour l'inclinaison ils le sont moins, mais pas à tel point cependant que l'interprétation des inversions de l'aimantation observées devienne téméraire, surtout quand elles se systématisent géographiquement, c'est-à-dire, quand à une inversion dans un hémisphère une autre correspond dans l'hémisphère opposé. Comme, d'autre part, le prélèvement d'échantillons pour la détermination de l'inclinaison seule, n'exige que la connaissance d'une verticale du bloc, par le niveau ou le fil à plomb simplement, n'importe qui peut l'opérer sans difficulté, ce qui importe beaucoup en pays écarté.

Quant à l'examen magnétique il se fera généralement au laboratoire, la stabilité de l'aimantation en garantissant le maintien durant le transport et même sous les chocs les plus énergiques (Chevallier). On se servira du magnétomètre (méthode de Gauss) ou de l'inductomètre (Chevallier). Le magnétomètre est le plus sensible mais a le tort de nécessiter, pour l'examen quantitatif, que l'on taille l'échantillon en forme de cube très soigné, travail long et coûteux. Les méthodes d'induction échappent à cet inconvénient mais sont moins sensibles. Par l'emploi combiné d'un dispositif de zéro et de lampes amplificatrices on réaliserait d'ailleurs sans grande peine une méthode d'induction sûre et rapide qui deviendrait sans doute la plus pratique pour les contrôles sys-

([1]RAYMOND CHEVALLIER: L'aimantation des laves de l'Etna et l'orientation du champ terrestre en Sicile du XII au XVIIème siècle. Thèse. Paris, 1925.)

tématiques, quand les échantillons afflueront de toutes les parties du monde. Personnellement et pour les trop rares examens que j'ai pu faire je m'en suis tenu au magnétomètre: des cubes de quelques centimètres d'arête, sciés au disque émerisé, puis rectifiés à la meule[2] ont été présentés au magnétomètre dans la position de Gauss la plus influente et, pour chaque face, dans les quatre postures possibles. La combinaison des déviations lues a fourni les composantes de l'aimantation parallèles aux arêtes et ceci à une fraction de degré près. Cette précision est d'ailleurs illusoire, car le repèrage géographique des échantillons ne pouvait prétendre à une aussi grande sûreté.

Les résultats ci-dessous se rapportent exclusivement à l'inclinaison magnétique. Selon M. Chevallier il vaudrait mieux, en principe, s'adresser à l' élément déclinaison, que les laves enregistreent plus correctement. Une étude systématique de l'aimantation des roches éruptives devra comprendre d'ailleurs les deux éléments directifs du champ, mais pour obtenir une première vue d'ensemble la recherche de l'inclinaison suffisait. Je l'ai faite dès 1910 sur des diabases recueillies par moi-même dans l'Isfjord du Spitsberg, puis, dès 1912, sur des basaltes de Disco (Groenland W) prélevés par l'Expédition suisse au Groenland et par la Station arctique danoise (Dr. Porsilde). En 1921 j'ai enfin pu compléter cette série septentrionale par des échantillons modernes du Jan Mayen.

D'emblée la plupart de ces spécimens arctiques et les meilleurs—ont marqué, fait surprenant même après la trouvaille de Brunhes à Pontfarein (Plateau central, France), une inversion du sens de l'inclinaison magnétique terrestre aux âges tertiaires. Voici d'ailleurs l'ensemble des résultats acquis; les données quantitatives s'y trouvent complétées par les indications qualitatives des blocs approchés, á l'état brut, du magnétomètre:

(A). Spitsberg, Isfjord, baie de Sassen; Diabases tertiaires (nappe à 300 m sur la mer). Trois échantillons: Le N° 2, refendu, donne quatre morceaux où l'on ménage des faces planes, inférieures ou supérieures horizontales *in situ*. Le spécimen N° 3 est mis en forme exacte de cube. On constate alors: l'échantillon N° 1 est aimanté nord à sa face supérieure, sud à la face opposée. Même polarité chez les quatre fragments du spécimen N° 2. Quant au cube taillé dans 3 il indique une inclinaison magnétique très faible et, semble-t-il, australe. Conclusion générale: inclinaison voisine de 0°, plutôt *australe*.

(B). Groenland, Disco, Godhavn, près de la Station arctique danoise; canyon de la Roedelv, à 30 m sur mer environ. Basaltes tertiaires; substance peu homogène en général. On y taille 8 cubes. Résultats: Les cubes N° 1 et 5 ont le pôle nord en bas, le pôle sud en haut et indiquent ainsi une inclinaison boréale. Les cubes N° 2, 3, 4, 6, 7 et 8 ont une polarité inverse et témoignent d'une inclinaison australe.

([2]J'ai été secondé dans ce long et délicat travail par MM. FORETAY, GASCHEN et F. ROCHAT.)

(C). Même localité, même âge mais blocs prélevés sur la terrasse dite de la "Femme de Lot" (masse volcanique en forme de tour haute et épaisse de quelques mètres). La "Femme de Lot" elle-même fournit un échantillon dans lequel on taille un gros cube. Les trois autres blocs, qui restent bruts, manifestent la diaclase en prismes hexagonaux.

Résultats: Les trois gros blocs bruts ont une polarité supérieure nettement nord, inférieure nettement sud, indiquant ainsi une inclinaison australe. Le cube donne: $I=53°$ australe.

Pour comparaison j'ai prélevé dans la base de la coulée basaltique, issue il y a deux siècles du cratère Esk de Scoresby, à Jan Mayen, (baie de Jameson), quelques échantillons dont l'un a fourni un cube. Pour tous le résultat a répondu à l'attente: polarité sud en haut, nord en bas; inclinaison indiquée: boréale, 82°.

L'inversion révélée ainsi par les laves septentrionales avait-elle sa contre-partie chez les laves de l'hémisphère sud? Il convenait de le rechercher.

Par l'entremise de M. C. E. Barton, de Brisbane, et les soins obligeants de MM. Richards, Gregory et Sir Edgeworth David, j'ai obtenu des échantillons australiens qui m'ont livré les résultats suivants:

(D). Australie, Queensland, entre Brisbane et Clarence. Basaltes du permocarbonifère. Cinq prélèvements. Aimantation mais de coulées diverses. Ces roches sont données comme tertiaires par Richards. Résultats: deux spécimens bruts donnent des indications ambigües; deux autres indiquent nettement une polarité sud en haut, nord en bas: un dernier bloc enfin témoigne plutôt du contraire mais peu nettement.

Un cube taillé dans le basalte d'Observation Hill, indique: Inclinaison boréale, 65°.

(E). Australie, New-South Wales, région Kiama-Wollogong. Basaltes du permocarbonifère. Cinq prélèvements. Aimantation généralement difficile à déterminer sur les échantillons bruts, plutôt sud en haut, nord en bas. Un cube donne sans ambiguité: inclinaison boréale, 87°.

Ainsi donc l'inversion du sens de l'inclinaison magnétique terrestre constatée dans l'hémisphère nord se retrouverait dans l'autre hémisphère. Si les recherches ultérieures corroborent cette constatation ses conséquences se devinent importantes pour l'histoire de notre globe; les pôles magnétiques y auraient effectué des déplacements énormes. Il convient donc de multiplier les investigations en les étendant, comme je l'ai demandé depuis longtemps et récemment encore dans la session de Madrid de l'Union géophysique et géodésique, à l'ensemble des nappes éruptives du globe. Un laboratoire concentrerait les échantillons et les étudieraient par une méthode simple et rapide, qu'il faut maintenant élaborer. Ce travail de longue haleine doit précéder toute spéculation théorique, laquelle ne saurait encore qu'être dangereuse.

Remarque finale. Tout ceci suppose, et exige, que l'état magnétique des roches examinées n'ait pas, dupuis l'époque de leur refroidissement *in situ*, changé soit sous l'action lente des siècles soit par suite des manipulations subies en dehors et dans le laboratoire, soit enfin du fait même de l'examen au magnétomètre. Les recherches de Brunhes et David, en Auvergne, celles de Chevallier à l'Etna, enfin les expériences de choc du même investigateur sur les laves siciliennes ont prouvé à l'évidence la stabilité extrême de l'aimantation des roches éruptives, des basaltes notamment. La place me manque pour développer ces preuves ici; le lecteur voudra bien se reporter aux travaux originaux.

J'observe enfin que si un lien existe entre l'axe de rotation de notre globe et son axe magnétique, les déplacements considérables que nos recherches décéleraient pour l'axe magnétique corroboreraient de façon inattendue l'hypothèse de grands déplacements de l'axe de rotation terrestre défendue par A. Wegener.

P. L. Mercanton.

Lausanne, octobre 1926.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE HUANCAYO MAGNETIC OBSERVATORY, JULY TO SEPTEMBER, 1926.

(*Lat. 12° 02′.7 S.; long. 75° 20′.4 W. or 5^h 01^m W. of Gr.*)

There were no magnetic storms during July or August.

There were no very great magnetic disturbances during September, but two periods of moderate disturbance are worthy of brief description. The first period commenced at about 16^h on September 8 and terminated at 1^h on September 10. During this time moderately large and rapid excursions were made by the horizontal-intensity trace, the most notable one being a large bay between 20^h and 21^h on September 8 occupying 33 minutes of time, the minimum (a very sharp point at 20^h43^m) being about 194γ less than the values of H before and after the bay. The second period of disturbance extended over seven and one-half days, commencing on September 14 at 13^h45^m with a rise in H of about 24γ, this increase occupying a period of seven minutes of time. Moderately abnormal and rapidly varying values of H prevailed during the remainder of the period, representing on the whole a diminished value of the component. The lower limits of registration were exceeded between 2^h and 3^h on September 16. Normal conditions were resumed by 5^h on September 22.

All times given are Greenwich mean time.

Richard H. Goddard, *Observer-in-Charge.*

Department of Terrestrial Magnetism,
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Huancayo Magnetic Observatory, Huancayo, Peru.

MAGNETIC STORM OF OCTOBER 14-16, 1926, AS RECORDED AT THE CHELTENHAM MAGNETIC OBSERVATORY.

(Greenwich Civil Mean Time.)

The principal portion of the storm began at 21^h, October 14, and ended at 5^h, October 16. From 17^h to 21^h on October 15 the motion of the magnets was so rapid that only at turning and halting points was a legible record made on the magnetogram. This was the period during which there was interference with the operation of telegraph lines. The amplitudes of the variations were as follows: Declination, $57'.1$; horizontal intensity, 419γ; vertical intensity, about 730γ; (the Z spot went below the limits of the paper twice between 7^h and 9^h on October 15.) The extremes occurred at the following times; all on October 15:

	West Decl'n	Horizontal Intensity	Vertical Intensity
	h m	h m	h m
Maximum	7 54	22 44	19 27
Minimum	0 07	7 00	7^h-9^h

GEORGE HARTNELL, *Observer in Charge.*

PROVISIONAL SUNSPOT NUMBERS FOR SEPTEMBER TO NOVEMBER, 1926.

Day	Sept.	Oct.	Nov.	Day	Sept.	Oct.	Nov.
1	45	29	. .	17	89	83	37
2	21	23	. .	18	112	62	26
3	28	. .	. .	19	111	55	21
4	21	. .	. .	20	106	31	53
5	39	37	. .	21	105	. .	. .
6	42	53	. .	22	89	. .	. .
7	43	69	28	23	85	. .	113
8	29	116	31	24	68?	38?	105
9	28	80?	35	25	70	62	. .
10	35	86?	50	26	. .	93	110
11	30	144	38	27	101	85	88
12	33	132	39	28	80	. .	89
13	37	151	40	29	57	50?	64
14	55	133	39	30	49	61	73
15	74	112	38			42	
16	73	116	39				
				Mean....	60.5	77.7	55.0

Zürich, Switzerland. A. WOLFER.

NOTES

23. *Vienna Zentralanstalt for Meteorology and Geophysics.*—This Institute, which was founded in 1851 at the instance of the Vienna Academy of Sciences, has reached its seventy-fifth anniversary. At the suggestion of the director, Dr. F. M. Exner, the Academy celebrated the event by issuing a *Festschrift* dedicated to the Institute; the volume, of about 200 pages, contains thirteen papers by Austrian and German geophysicists.

24. *International Geodetic and Geophysical Union, 1927.*—Information has been received that the next meeting of this Union and of its Sections will be held at Prague, September 4-11, 1927.

25. *International Section of Terrestrial Magnetism and Electricity, Bulletin No. 6.*—During November there was issued from the Central Bureau Bulletin No. 6, of 40 octavo pages, containing the "Preliminary Reports on Subjects of Investigation."

26. *Personalia.*—We regret to record the deaths on August 31 of Dr. *Walter Budig*, of the Prussian Meteorological Institute, and on November 15, at the age of 78 years, of the well-known investigator of atmospheric electricity, Prof. *Franz Exner*, professor emeritus of physics at the University of Vienna; also on October 6, there died, at the age of 78 years, Prof. *Francis E. Nipher*, professor emeritus of physics at Washington University, St. Louis, Missouri. Besides other fruitful investigations, it may be recalled that Prof. Nipher made the first detailed magnetic survey of Missouri.

Dr. *F. W. Lindholm* has been appointed as successor to Prof. *C. Dorno* to the directorship of the Physical-Meteorological Institute at Davos, Switzerland. The Royal Society of London has awarded the Rumford Medal to Sir *Arthur Schuster*, F. R. S., for his services to physical science, especially in the subjects of optics and terrestrial magnetism. Dr. *Egon Schweidler* has been appointed professor of experimental physics at the University of Vienna, and Dr. *G. Angenheister*, of the Geodetic Institut in Potsdam, honorary professor at the Technische Hochschule, Berlin. *Greenleaf W. Pickard* was awarded the medal of honor of the Institute of Radio Engineers, in recognition of his contributions to the advancement of radio science. Dr. *H. U. Sverdrup* has been appointed professor of dynamic meteorology and director of Section B of the Geophysical Institute of the Bergen Museum, effective July 1, 1926. Sr. *G. C. Plate* has succeeded Sr. *F. Burmeister* as director of the Meteorological Office of Argentina at Buenos Aires. Dr. *C. A. Heiland* has resigned his position as representative in the United States and scientist for the Askania-Werke of Berlin in order to accept the newly-established professorship of geophysics at the Colorado School of Mines, Golden, Colorado.

27. *Future Cruise of the Carnegie.*—The Trustees of the Carnegie Institution of Washington at their annual meeting on December 10 made provision for required repairs of the *Carnegie* in 1927, with the expectation of a three-years' cruise by the vessel to begin in 1928 and to include magnetic, electric, and oceanographic observations.

THE LUNAR-DIURNAL MAGNETIC VARIATION AND ITS RELATION TO THE SOLAR-DIURNAL VARIATION.

By J. Egedal.

The lunar-diurnal magnetic variation is not large, but still the study of the phenomenon may be of interest, as it may throw light on some other geophysical problems.

At present it is not claimed that the observed lunar-diurnal variation is due to a direct magnetic effect of the Moon, although such an effect may exist. Assuming the magnetic state of the Moon to be similar to that of the Earth, the variation produced in this way on our magnets would be very small, and of a type different from that observed. The action of the Moon must therefore be indirect, and it may be a screen-effect or the effect of attractive forces acting on the Earth. Even if solar-diurnal variations are produced by electric particles coming from the Sun, it is not probable that the Moon, acting on those particles, could produce a variation like that observed. It is therefore natural to expect that the lunar-diurnal magnetic variation originates from the mechanical action of the Moon on the Earth and her atmosphere.

The Moon produces a variation of pressure in the atmosphere and in the Earth, and it may be that this variation itself produces a magnetic variation. The pressure is greatest at upper and lower transit of the Moon, but at those instants the lunar-diurnal variation of the horizontal intensity has neither maximum nor minimum. Therefore it is not likely that the pressure itself produces a magnetic variation. But the variation of the pressure may cause some of the conditions to vary which determine the solar variation; thus it may cause the electric conductibility or susceptibility of the Earth and the conductibility of the atmosphere to vary.

In consideration of the above we are going to base our investigation on the following *working hypothesis:* The lunar-diurnal variation is due to a variation of the solar-diurnal variation.[1]

The solar and lunar variations are found by summing up the values of the magnetic elements for each solar and lunar hour from 0 to 23, and then calculating the variations from the derived means. Values disturbed beyond a certain limit are to be excluded. The solar-diurnal variations derived from *a whole year* are characterized by one maximum and one minimum. The difference between maximum and minimum is here called the daily oscillation. It is found approximately by subtracting the lowest hourly value from

[1]Chambers (*Phil. Trans.*, vol. 178, A): The phenomenon dealt with (the lunar-diurnal variation) is "not a lunar-diurnal variation but solar-diurnal variation, which depends upon the relative positions of the Sun and Moon."

the highest. The daily oscillation may be used as a measure of the forces which produce the solar variation. The lunar-diurnal variation is mainly a double wave, and here we postulate that the 12-hour term of the harmonic formula gives a good representation of the variation. If the lunar-diurnal variation is derived from reliable magnetic registrations over a period of many years, then the 12-hour term is predominant. This shows that there is some reason to postulate as we have done.

Let the solar-diurnal variation of the declination be so given that the maximum and the minimum are 6 lunar hours apart, which is nearly the case in nature. Let the lunar-diurnal variation be superposed on the solar variation. As the lunar day is about 0.8 solar hour longer than the solar day, the lunar hours are displaced that amount every day in relation to the solar hours. If one of the lunar maxima for a certain day coincides with the solar maximum, then one of the lunar minima coincides with the solar minimum, that is to say, a combined oscillation is formed with its amplitude equal to the sum of the amplitudes of the solar-diurnal variation and of the lunar-diurnal variation. After seven days and some hours the lunar maximum in question has reached the solar minimum, and the second lunar minimum coincides with the solar maximum, that is a new oscillation is formed whose amplitude is equal to the difference in amplitudes of the solar-diurnal variation and of the lunar-diurnal variation. After the lapse of seven days and some hours we again get an augmented oscillation; then likewise a diminished one and so on. J. de Moidrey, Zi-ka-wei, has calculated the variation of the daily oscillation of the declination during a lunation. He found an amplitude of 0.′43 (1878-1899), but the amplitude of the lunar variation is about 0.′14 (1897-1903). From this it seems doubtful if the lunar-diurnal variation is superposed on the solar one. For a certain solar hour the magnetic elements vary in the course of one lunation in the same way as the lunar-diurnal variation. Figee, Batavia, has found that this lunar variation is very pronounced in the day hours, and its amplitude for a certain hour is nearly four times the amplitude of the lunar-diurnal variation.

From the above it is seen that our working hypothesis does not disagree with the stated facts.

S. Chapman[2] assumes that the lunar-diurnal variation is of tidal origin, since it is a semidiurnal phenomenon, and its amplitude depends on the inverse cubes of the Moon's distance from the Earth. Further he has attempted[3] to show that the lunar-diurnal variation depends on the declination of the Moon, which was to be expected if the lunar-diurnal variation is of tidal origin.

Using our working hypothesis and other assumptions, we are now going to investigate a problem related to the problem just mentioned, which was treated by S. Chapman.

[2] *Phil. Trans.*, vol. 225, A, London.
[3] *Terr. Mag.*, vol. 22, p. 121.

Since the lunar-diurnal variation, according to the working hypothesis, is produced by a variation of the solar variation, it may be expected that the amplitude of the lunar-diurnal variation is proportional to the forces producing the solar variation and therefore also to the daily oscillation, the latter being considered as the effect of those forces. It has been assumed above, that the pressure variation produced by the Moon in the crust of the Earth and on the atmosphere might cause some of the conditions to vary on which the solar variation depends. It is therefore necessary to consider the pressure variation.

By summing up for the half of the Earth towards the Moon the effects of the horizontal tide-producing forces lying in the meridian plane of a certain place for the instant when the Moon is on the meridian, the amplitude of the pressure variation is found proportional to $\cos^2 z$, where z is the geocentric zenith distance of the Moon[4]. If the Moon revolved in the equatorial plane the amplitude of the pressure variation would be proportional to $\cos^2\phi$, where ϕ is the geographic latitude of the place considered. In Chapman's article (see footnote 2) the atmospheric tide is supposed "to vary in amplitude proportionately to $\cos^2\delta$, where δ is the declination of the Moon." It is seen that a difference exists in the points of view. The Moon moves in a plane inclining 5° to the ecliptic, and we make the amplitude of the pressure variation proportional to $f(\phi)\cos^2\phi$, where $f(\phi)$ is equal to unity at the equator and indicates how much $\cos^2\phi$ is to be augmented at higher latitudes in relation to the value at the equator on account of the Moon's variation in declination. If $f(\phi)$ is computed for the Moon in the ecliptic instead of in its own plane, the maximum resulting error in $f(\phi)$ does not exceed 1 per cent for a range of latitude from 0° to ±60°. Hence the table below has been computed as if the Moon's path lay in the ecliptic, making the computation much simpler.

Suppose the Moon to move in the ecliptic. It would be in a plane inclined at an angle, ϵ, to the equatorial plane; then, for a place in terrestrial latitude, ϕ, the geocentric zenith distance of the Moon at upper transit is:

$$z=\phi+\epsilon\sin\lambda$$

where λ is the celestial longitude of the Moon. In forming the mean of $\cos^2 z$ for the interval of λ from 0 to 2π for the place considered and for the equator, we get:

$$f(\phi)\cos^2\phi=\frac{\frac{1}{2\pi}\int_0^{2\pi}\cos^2(\phi+\epsilon\sin\lambda)d\lambda}{\frac{1}{2\pi}\int_0^{2\pi}\cos^2(\epsilon\sin\lambda)d\lambda}$$

[4]It is hoped that careful consideration may be given this method of treatment in future investigations of the problem.

or

$$f(\phi) = \frac{\int_0^{2\pi} \cos^2(\phi + \epsilon \sin \lambda) d\lambda}{\cos^2\phi \int_0^{2\pi} \cos\ (\epsilon \sin \lambda) d\lambda}$$

By approximate computation and then graphical interpolation the following Table 1 was obtained:

TABLE 1.

ϕ °	$f(\phi)$	ϕ °	$f(\phi)$
0	1.000	30	1.030
10	1.004	40	1.062
20	1.012	50	1.124
		60	1.270

Let L be the amplitude of the 12-hour term of the harmonic formula for the lunar-diurnal variation, S the daily oscillation for the magnetic elements, and $f(\phi)$ the above defined function, then, if our assumptions are in agreement with the phenomena of nature, we should expect to get:

$$\frac{L}{S \cos^2\phi f(\phi)} = C \text{ (constant).} \tag{1}$$

If L_E is the means of the numerical values of the maxima and the two minima of the inequalities of a given lunar-diurnal variation, the following formula is a sufficiently accurate approximation:

$$\frac{L_E}{S \cos^2\phi} = C_E + \alpha(\phi) \tag{2}$$

where C_E is a constant, and where α (ϕ) for $\phi < 56°$, does not surpass 10 per cent of the constant C_E. Values found for the constant will differ much more, of course.

In order to test the formulæ, all available lunar-diurnal variations were examined. The data have been compiled from different sources, but it is not worth while to give a minute description of the material.

S_D being uncertain near the equator, the formulæ could not be applied to the lunar-diurnal variation of the declination for these regions (Colaba). The data from the Greenwich Magnetic Observatory not agreeing with our assumptions have not been used in the final results. The lunar-diurnal variation of the declination for Toronto has been derived twice by Sabine. Both determinations have been used here.

It will be seen that the formulæ have been applied to observations from different parts of the Earth.

Originally the formulæ had been arranged for the declination. They have been applied to the horizontal and vertical forces too, although the data concerning the lunar-diurnal variation of these magnetic elements are not entirely reliable.

Observatory	Latitude	Period	L_E	L	S	$\frac{L_E}{S\cos^2\phi}$	$\frac{L}{S}$	$\frac{L}{S\cos^2\phi}$	$f(\phi)$	$\frac{L}{Sf(\phi)\cos^2\phi}$	
	° ′		γ	γ	γ						
Seddin (Y)	52 17 N	1917–22	0.79	0.77	42.5	0.0497	0.0181	0.0484	1.146	0.0423	
Potsdam (Y)	52 23 N	1891.5–05.5	.....	0.829	40.7	....	0.0204	0.0546	1.147	0.0476	
Zi-ka-wei (Y)	31 13 N	1897–03	.....	1.44	45.4	....	0.0317	0.0434	1.033	0.0420	
Batavia (D)	6 11 S	1883/84–98/99 Oct.–March	0′.170	0′.168	4.′17	0.0413	0.0403	0.0408	1.002	0.0407	
Toronto I (D)	43 40 N	1842.5–48.5	0.227	0.215	8.93	0.0486	0.0241	0.0460	1.080	0.0426	Disturb. >2′9 excluded
" II (D)	43 40	1842.5–48.5	0.331	0.320	"	0.0709	0.0358	0.0685	"	0.0634	" >5′0 "
St. Helena (D)	15 57 S	1842.7–47.7	0.094	0.082	1.97	0.0516	0.0416	0.0451	1.007	0.0448	
Hobarton (D)	42 53 S	1841–49	0.148	0.149	8.25	0.0334	0.0181	0.0337	1.077	0.0313	
Philadelphia (D)	39 58 N	1840–45	0.232	0.207	8.0	0.0494	0.0259	0.0441	1.061	0.0415	
Rude Skov I (D)	55 51 N	1908–18	0.111	0.109	7.15	0.0493	0.0152	0.0484	1.190	0.0407	
" " II (D)	"	1908–12	0.100	0.097	6.78	0.0468	0.0143	0.0454	"	0.0382	Not used in the mean.
Greenwich (D)	51 28 N	1848–63, 68–14	.....	0.272	(6.5)	....	0.042	0.108	1.142	0.095	S estimated.
Kew (D)	51 28 N	....	0.175	.....	(6.5)	0.0694	....	......	....	....	S estimated.
Pekin (D)	39 57 N	....	0.068	.....	(3.6)	0.0322	....	......	....	....	$S = D_{7\,h\,a.m.} - D_{7\,h\,p.m.}$
Cape (D)	33 56 S	....	0.160	.....	(4.0)	0.0581	....	......	....	....	S estimated.
Melbourne (D)	37 49 S	1858–63	0.158	.....	9.72	0.0261	....	......	....	....	
					Mean	0.0446 ± 0.0041		0.0473 ± 0.0029		0.0437 ± 0.0025	
			γ	γ	γ						
Seddin (X)	52 17 N	1917–21	0.435	0.355	30.6	0.0380	0.0116	0.0310	1.146	0.0271	
Potsdam (H)	52 23 N	1891.5–05.5	.....	0.342	28.1	....	0.0122	0.0336	1.147	0.0293	
Batavia (H)	6 11 S	1883–99	0.655	0.636	49.0	0.0135	0.0130	0.0131	1.002	0.0131	
Toronto (H)	43 40 N	1843.5–48.5	0.527	0.473	26.7	0.0377	0.0177	0.0339	1.080	0.0314	
Colaba (H)	18 54 N	1871/72–88/89 Nov.–Jan.	1.275	1.30	38.9	0.0366	0.0334	0.0373	1.011	0.0369	
Prag (H)	50 05 N	1840–49	0.93	0.72	30.6	0.0738	0.0235	0.0571	1.105	0.0517	
					Mean	0.0399 ± 0.0097		0.0343 ± 0.0058		0.0316 ± 0.0052	
			γ	γ	γ						
Seddin (Z)	52 17 N	1917–21	0.39	0.41	23.6	0.0442	0.0174	0.0465	1.146	0.0406	
Colaba (Z)	18 54 N	1870/72–88/89 Nov.–Jan.	0.50	.....	11.3	0.0494	....	......	....	....	
Batavia (Z)	6 11 S	1883/99 Ap.–Sep.	1.36	.....	34.0	0.0405	....	......	....	....	
" (Z)	"	" Oct.–Mar.	1.36	.....	42.6	0.0323	....	......	....	....	
Toronto (Z)	43 40 N	1843.5–48.5	0.306	.....	23.0	0.0254	....	......	....	....	
					Mean	0.0384 ± 0.0043		......	....	....	

In Table 2 the data and the results have been collected. Here are given: the name and latitude, ϕ, of the observatory; the magnetic element (D, Y, X, H, or Z) utilized; the period for which the solar and lunar variations have been derived; all quantities to be used in the formulæ; and the results from formulæ (1) and (2). As regards formula (1), the computation has been performed successively in order to give an idea of the usefulness of the different operations. Means have been calculated for the quantities which were expected to be constant. Formula (2) has been applied to nearly all the data, while formula (1) has been applied only to the more reliable data.

On inspecting Table 2 it will be seen that the quantities which were expected to be constant differ rather much. As to the means of the quantities for declination there is no disagreement: the mean result derived by formula (2) is, as might be expected, a little greater that that derived by formula (1). Examining the quantities derived by formula (1) for the declination, it is seen that the quantities differ, but it must be remembered that very often the lunar-diurnal variation is of an uncertain character. The declination gives the most marked lunar-diurnal variation, and the quantities derived from this element by formula (1) are therefore the more suitable ones for determining whether the true value of the quantities is really a constant.

The mean error of the mean of the ten quantities, derived from D and Y, is but 6 per cent of the mean itself. This makes it to some extent certain that the quantity called C, in reality, has a constant value, and that the deviations from the mean arise from errors in the material and from the different ways in which the computations are made. Although only a small number of observatories is at hand, it will be seen from Table 2 that the ten quantities are distributed about the value 0.0420 in such a way that the proposition concerning the realty of the constant C is supported.

A further examination of the quantities derived for the horizontal and vertical forces would require more and better data.

It is to be hoped that the results derived from the declination will be discussed in the future. The best contributions to the discussion are to be expected from such magnetic observatories as are able to give the data in convenient form for the calculation of the quantities. The observatories might also give the quantities themselves.

The working hypothesis may be considered as based on a rough first approximation. *Given in general, the hypothesis would be of the following form: Lunar-diurnal variation is due to a variation in the solar-diurnal variation, and to a variation in the magnetic disturbances.*

Many considerations have been employed in deriving the formulæ. From the above it will be seen that no cause of the relation between the solar and lunar-diurnal variation is pointed out,

although it has been assumed that the pressure in the Earth or in the atmosphere might cause variations in some of the conditions on which the solar-diurnal variation depends. As to the conditions it need only be stated that the magnetic susceptibility of the crust of the Earth may change on account of pressure variation.

Results.

If future investigations confirm the relation between the solar and lunar-diurnal variations supposed above, and supported by the quantities derived from the formulæ, then the results would be:

1. The lunar-diurnal magnetic variation is a gravitational phenomenon;
2. The relation between the solar and lunar-diurnal variation is known; and
3. A very useful test of hypotheses on the solar-diurnal variation is at hand.

I take this opportunity to thank Dr. V. H. Ryd, who has supported and encouraged me during the work, and Miss Ester Jensen, who has derived the lunar-diurnal variation of the declination for Rude Skov from the observations of 1908-1918.

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